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AN EXAMINATION OF AEROBIC POWER  
AND BODY COMPOSITIONAL CHANGES ASSOCIATED  
WITH OMNIKINETIC TRAINING



DIANNA L. SATRE

A THESIS  
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The undersigned certify that they have read, and  
recommend to the Faculty of Graduate Studies and Research, for  
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AN EXAMINATION OF AEROBIC POWER  
AND BODY COMPOSITIONAL CHANGES ASSOCIATED  
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## ABSTRACT

This study was comprised of 36 volunteer male and female subjects who trained for a ten week period using hydraulic resistive equipment, and were compared to a control group consisting of 29 male and female subjects. All subjects underwent a pre-test and a post-test designed to measure aerobic power and per cent body fat. T-tests demonstrated there was no significant difference between these groups prior to training with respect to  $VO_2\text{max}$  measures. However, three way analysis of variance on post-test  $VO_2\text{max}$  demonstrated a significant difference between these groups following training. The results of this analysis were not significantly influenced by sex, age or initial  $VO_2\text{max}$ . An examination of the treatment group means from pre-test to post-test indicated that the training group experienced a 12% increase in aerobic power. T-tests also demonstrated no significant difference between the control group and the training group prior to training with respect to per cent body fat measures. However, a three way analysis of variance also demonstrated a significant difference between these groups following training. An examination of the treatment group means for per cent body fat indicated that the training group experienced an absolute decrease of 1.87%. This absolute decrease is representative of a relative decrease of 8.1%. The three way analysis of variance on post-test per cent body fat also revealed that those individuals who were initially classified as showing a high percentage of body fat tended to experience greater decreases in body fat.



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## CHAPTER I

### STATEMENT OF THE PROBLEM

#### Introduction

The value of resistance exercise as a training mode has long been recognized. As early as 1948, Delorme and Watkins (28) advocated the first isotonic progressive resistance program. Later, in 1953, Hettinger and Muller (44) initiated research on isometric weight training programs. More recently, research has focused on resistance training involving isokinetic exercise which "allows movement at a mechanically fixed rate of speed and offers resistance inherently proportional to the muscle's dynamic tension developing capacity at every point in its shortening range." (59)

A number of variable resistance exercise systems have been designed in an effort to make the best practical use of training principles. Many of these systems consist of a number of machines designed to allow for joint movements which will accommodate the development of specific muscle groups. Each system is unique in the manner in which it provides variable resistance throughout the range of motion.

One of the most recent exercise systems developed is the Hydra-Gym system which is based on a new concept in resistance training referred to as omnikinetic training. Omnikinetics, as introduced by the manufacturers of Hydra-Gym equipment, is similar to isokinetic exercise in that it involves dynamic muscular contractions in which the force generated is, for all practical purposes, equal to the resistance. (59) However, omnikinetics varies both the speed of movement and the resistance, whereas isokinetics involves constant velocity.



The Hydra-Gym equipment operates through the use of a hydraulic cylinder which has a valve setting to increase the resistance through any given range of motion. As the lever arm of the machine is forced to move by the muscle, hydraulic fluid is forced through an opening inside the cylinder. The size of this opening is determined by setting the valve. "The uniqueness of Hydra's omnikinetic machines lies partly in the fact that while the valve is pre-set, the rate at which the limb moves against the resistance of the cylinder is determined not so much by the machine as it is by the contractile properties of the user's muscle groups." (59:11) Thus, at any given valve setting, the user receives optimal resistance with each repetition performed, even as the muscle fatigues. Although the speed of movement may decrease with muscle fatigue, the effective resistance load remains the same.

Most of this hydraulic resistive apparatus also develops balanced muscle groups by working both agonistic and antagonistic muscles during the same exercise set. This tends to reduce the time needed to work all the major muscle groups and provides a rhythmic pumping of blood through the muscles.

Such a system may have practical advantages in conditioning the cardiovascular system since anything from low power output with small muscle groups to ultra-high concurrent power outputs with larger muscle groups can be achieved. (73) If a training program designed for use on this equipment were to take into consideration the usual guidelines followed when prescribing a program for improvement of aerobic power, then theoretically, there should be an improvement.





## The Problem

The primary purpose of this study was to critically examine whether any significant changes occur in aerobic power when individuals are subjected to a circuit training program utilizing hydraulic resistive equipment.

A secondary purpose of the study was to observe any changes which may have occurred in body composition, specifically per cent body fat, as a result of this program.

## Need for the Study

The benefits of regular physical activity are well documented. (6,39,64,67,79,84) In an effort to involve a greater percentage of our general population in regular activity, there is a need to direct research at finding alternative modes of exercise suitable for achieving a desirable personal level of physical fitness.

Further, much of the research conducted on resistance exercise to date is primarily concerned with strength gains rather than gains in aerobic power. (10,19,47,74,80,96) There is a need to critically examine all the possible benefits of resistance exercise training programs, in an effort to attain maximal benefits from them.

Since no research has currently been conducted using hydraulic resistive equipment there is also a need to critically examine the training benefits that may be associated with various programs using this equipment.





### Null Hypothesis

The null hypothesis upon which this investigation was based asserts that no significant change would occur in aerobic power or per cent body fat as a result of the training program introduced here.

### Limitations

1. The study was limited to volunteer subjects between the ages of 18 and 45.
2. The training program was limited to a maximum of thirty minutes per session, three times per week for a period of ten weeks.
3. The study was limited to a series of ten exercises using Hydra-Gym equipment.
4. Training sessions were scheduled to accommodate the individuals participating in the program and the only stipulation was that they did not train three days consecutively.
5. There was no control over the time of day for testing subjects.

### Delimitations

1. Subjects participating in the program were asked to maintain their current patterns of physical activity throughout the ten week training period.
2. An effort was made to control alcohol, cigarette, food, caffeine and excessive activity prior to testing sessions by providing an instruction sheet for each subject before they were tested.
3. An attempt was made to match the control group with the training group by having each member of the training group choose a control



subject with characteristics similar to themselves.

4. Training sessions were supervised in an effort to achieve maximal effort from subjects during each session.

#### Definition of Terms

1. Resistance Exercise - a muscular contraction against any form of external resistance.
2. Variable Resistance Exercise - a muscular contraction against a movable resistance which varies in magnitude throughout the range of motion.
3. Isokinetic Exercise - a form of variable resistance exercise in which muscular contractions are performed at a constant velocity and resistance is accommodating to the maximum muscle force throughout this range of motion. (58)
4. Isotonic Exercise - a form of exercise in which the muscle shortens with varying tension while lifting a constant load. (39)
5. Isometric Exercise - a form of exercise in which tension is developed, but no change occurs in length. (39)
6. Omnikinetics - a form of variable resistance exercise that allows for optimal self accommodating resistance at varying speeds which are dependent upon the muscle's contractile properties.
7. Agonist - the muscle group which initiates a particular movement, usually through a shortening of the muscles involved.
8. Antagonist - the muscle group which opposes the action of the agonist.



9. Power Output - an expression of the amount of work performed per unit of time.
10. Strength - the force a muscle or muscle group can exert against a resistance in one maximal effort. (39)
11. Interval Program - a program characterized by short but regularly repeated periods of work interspersed with appropriate periods of relief.
12. Aerobic Power - ( $\dot{V}O_{2\max}$ ,  $M\dot{V}O_2$ ) - the rate at which oxygen is transported to and consumed by the working muscles.





## CHAPTER II

### REVIEW OF LITERATURE

A considerable amount of research has focused on variable resistance training throughout the years. However, to date no research has been conducted using hydraulic resistive equipment which was used in this study. It therefore became necessary to review the literature of varied related areas in order to develop a suitable training program for this study. The review of literature has thus been organized under the following headings; training benefits associated with variable resistance training programs, a comparison of interval and continuous training and finally, considerations in developing an aerobic training program.

Further, there are a number of testing procedures utilized to measure aerobic power and per cent body fat and it becomes necessary to review the literature in this area in order to assess the available techniques. This literature will be reviewed under the following headings; measuring aerobic power and techniques for assessing body composition.

#### Training Benefits Associated with Resistance Exercise Programs

Over the years much of the literature dealing with resistance exercise has focused on strength gains and a comparison of strength gains observed for different types of resistance exercise.

Such research began with the work of Delorme and Watkins (28) who first attempted to systematize procedures for isotonic training. The





work protocol of Delorme and Watkins for load-resisting exercise, commonly referred to as progressive resistance exercise (PRE), set the stage for further research dealing with alternative techniques for PRE and comparisons of these different techniques. (10,17,62,103)

The use of isometric exercise as a means of producing strength gains also received considerable attention in the early research dealing with resistance exercise. (23,44,63)

Both types of exercise have proven effective at improving strength gains but comparisons between these two types of training has produced conflicting results. Some investigators have reported isotonic training to be superior to isometric training (11,26,77) while others have reported isometric training to be superior. (44,68) There has also been research which demonstrates no significant difference in strength gains produced by either isotonic or isometric exercise. (9,19,80)

The conflicting evidence with regards to the comparison between isometric and isotonic exercise is partially explained by the difficulty investigators encounter when attempting to equalize the intensity of training for the two methods due to the obvious difficulty equating work loads. Further, the technique used to measure strength gains will strongly influence the results, due to the specificity of training. (6,20,93)

In the mid-to-late sixties a new concept of resistance exercise called isokinetic exercise emerged. (47,73) "The isokinetic contraction resembles the isotonic contraction, since the joint moves through a range of motion, but the speed of movement may be held constant by a special device." (20:83) This allows for the development of maximal tension throughout the full range of motion rather than the muscle groups



contracting at different percentages of maximum through the range of motion as is the case with isotonic exercise.(73) Isokinetics also allows for training speeds to vary from  $0^{\circ}$  to  $360^{\circ}$  per second. "Matching the speed of training to the speed of performance may be important in light of recent work concerning the specificity of training." (74:262)

Thus far the studies investigating isokinetic training procedures are few and are somewhat limited in scope. (47,58,66,74,92)

Pipes and Wilmore (74:262) investigated differences between isotonic and isokinetic training procedures with regards to their "ability to affect changes in muscular strength, body composition, anthropometric measures and selected motor performance tasks." Strength gains were significant for both the isotonic group and for the two isokinetic groups (high speed and low speed) as compared to a control group. Both isokinetic groups also exhibited significantly greater strength gains than the isotonic group and the high speed isokinetic group showed significantly greater strength gains than the low speed group, even when both groups were tested at low speeds.

Thistle et al. (92) compared all three types of resistance exercise: isometric, isotonic and isokinetic. Following an eight week training session, the isokinetic group achieved significantly greater strength gains than did either the isotonic or isometric group. The isotonic group also achieved significantly greater gains than did the isometric group.

To date only one study has made an effort to compare two well known variable resistance exercise systems, which are the Nautilus equipment and the Universal Gym equipment. Coleman (22) had one group train on





each system for a period of ten weeks. The program utilized with each system was based on the protocol recommended by the manufacturers of each system. The Nautilus group performed one set of each exercise using a weight load that could be lifted between 10 and 12 times. The Universal Gym group performed two sets of each exercise using weight loads equal to ten RM and eight RM, respectively. Significant gains in strength were reported for both groups, with no significant difference between the two training groups.

Although much of the literature to this point has concentrated on strength gains as a result of varying types of resistive exercise, there is also considerable evidence to support changes in body composition as well. Significant increases in lean body weight and decreases in absolute and relative body weight are well documented for isotonic weight training. (16,21,24,60,74,96)

Wilmore (96) examined body compositional changes in men and women as the result of a ten week progressive weight training program. The body composition measures used were lean body weight, absolute and relative body fat as determined by hydrostatic weighing, seven skinfolds and finally, 15 and 17 girths respectively for women and men. Significant reductions in five of seven skinfolds were observed in women, but only one skinfold decreased in men. The absolute decrease in per cent body fat was 1.86 and 1.32 for women and men, respectively. This change reflected a relative decrease in body fat of 7.59 per cent and 9.99 per cent in women and men respectively.



Clements (21) also reported a significant decrease in body fat as the result of a 14 week circuit training program. Subjects trained three times per week for 35 minutes per session. Each session consisted of a series of ten exercises.

Body composition was assessed using three skinfold measurements to determine body density which was then substituted into the formula of Keys and Brozek (54) to determine per cent body fat. The training group experienced a significant decrease in body fat when compared to a control group. Further, an initially higher fat group experienced a significantly greater decrease in body fat than did an initially low fat group.

Mayhew and Gross (60) evaluated the effects of circuit weight training on the body composition of college women. Body composition was assessed by seven skinfolds, four skeletal diameters, eight muscular girths and total body potassium. The training group exercised 40 minutes per session, three times per week for nine weeks. Two sets of exercises were performed during each workout using the ten repetitions maximum technique. (28) Skinfold thicknesses were unaffected but there was a significant increase in total body potassium, indicating an increase in lean body mass.

Coleman (22) compared two types of variable resistance exercise systems, using work protocols recommended by the manufacturers. Body composition was assessed using specific skinfold and girth measurements as described by Wilmore and Behnke. (98) During the course of the program, total body weight increased and the mean thickness of each skinfold site decreased significantly. An absolute decrease of 1.22 per cent and 1.29 per cent body fat was observed for the two groups. This change





represented a relative decrease of 9.11 per cent and 9.35 per cent for each of the two groups.

Gettman et al. (40) also reported changes in body composition as the result of circuit weight training. Subjects in this particular study trained for 20 weeks and were randomly assigned to one of three groups; control, circuit weight training, and running. Body composition was assessed using underwater weighing and per cent body fat determined using the formula of Brozek et al. (15). A significant decrease of 1.7 per cent body fat was observed.

In a more recent study by Gettman et al. (41) the benefits of circuit weight training were further examined. In this particular study absolute decreases of three per cent for males and 2.8 per cent for females were reported. These changes were representative of a relative decrease of 13.3 and 10.4 per cent for males and females, respectively.

Pipes and Wilmore (74) also reported significant decreases in absolute and relative body fat as a result of isokinetic training at both high speeds and low speeds. The high speed group experienced a significantly greater decrease than did the low speed group.

The literature focuses little attention on the possible improvements in aerobic power which may be associated with weight training exercise.

Nagle and Irwin (69) reported no significant improvement in cardiovascular function in subjects trained on high or low resistance weight lifting programs relative to a control group engaged in mild recreational activity.

The work capacity of weight lifters on a bicycle ergometer has been



reported as not being significantly greater than that of the general population. (36,55,81) Saltin and Astrand (81) examined the maximal oxygen uptake of international calibre athletes and reported that although weightlifters had values significantly greater than the untrained group, they had the lowest values when compared to other groups of athletes.

Nupp (70) examined the cardiovascular improvement associated with four different training programs:

- (1) Progressive resistance running
- (2) Fartlek training
- (3) Interval training
- (4) Weight training

The weight training group performed three weight lifting exercises designed specifically to tax the cardio-respiratory system. All four groups also performed a circuit training program aside from the program they were assigned to. Following ten weeks of training each group was assessed for cardio-respiratory improvement based on performance time in a mile run. The weight training group showed significantly less improvement than the other three groups. However, the assumption that performance in a mile run is indicative of cardio-respiratory improvement is somewhat questionable. (2,38) Secondly, no consideration was given to the specificity of training associated with these conditioning programs.

Gettman et al. (40) examined the cardio-respiratory effects of circuit weight training over a 20 week period. Subjects were randomly assigned to one of three groups; control, circuit weight training or continuous running. There were 20 subjects in the control group and



the circuit weight training group while the running group contained 30 subjects. Aerobic power was assessed using a maximal treadmill test. The circuit weight training group exercised on Universal Gym apparatus. Each circuit consisted of ten exercises. The weight for each exercise corresponded to approximately 50 per cent of each individual's maximum. The number of repetitions progressed from ten to 20 for the first six weeks and were then reduced to 15 per set for the remaining 14 weeks since subjects could not complete two circuits when performing 20 repetitions. The rest period between sets of each exercise was 30 seconds and was reduced gradually to 20 seconds. Two circuits were completed each workout. This program resulted in no significant increase in  $VO_{2\max}$  when expressed in ml/kg/min.

However, in a more recent study, Gettman et al. (41) reported improvements in aerobic power of 12 per cent for males and 13 per cent for females following participation in a circuit weight training program. The program followed was similar to the one used in the earlier study by Gettman et al. (40) with some modifications. In this particular study subjects worked between 40 to 60 per cent of their maximum one time lifting capacity, doing as many repetitions as possible during a 30 second time interval followed by a 30 second relief interval. One circuit consisted of ten stations and subjects performed three circuits for a total workout time of 30 minutes.

This program involved a timed work interval during which subjects performed between 12 and 15 repetitions unlike the previous study by Gettman et al. (40) in which subjects performed 15 repetitions with no time restriction. Introducing a timed work interval may have increased the rate of work and hence increased the intensity of the workout. Fur-







ther, three circuits were performed per workout in the more recent study (41) as opposed to only two in the earlier study. (40) This work protocol would have considerably increased the total work performed with each workout and may explain the different results observed in these studies.

The work protocol used by Gettman et al. (41) is characteristic of an interval training program, unlike much of the earlier research in which the work protocol was based on the original work of Delorme and Watkins. (28)

An interval type of circuit training program may be the key approach to take if an improvement in aerobic power is of prime concern.

#### A Comparison of Interval and Continuous Training

A review of the literature in this area indicates that interval training can be an effective means for inducing improvements in aerobic power.

With very short work periods of about 30s or less, a very severe workload may be imposed upon both muscles and oxygen-transporting organs without the engagement of anaerobic processes leading to any significant elevation of the blood lactate. It is thus possible to select the proper workload and work and rest periods in such a manner that the main demand is centered on (1) muscle strength without a major increase in the total oxygen uptake; (2) aerobic processes without significantly mobilizing anaerobic processes; (3) anaerobic processes without maximal taxation of the oxygen-transporting organs; and (4) both aerobic and anaerobic processes simultaneously. (2:401)

Astrand et al. (3) indicated that with intermittent exercise of 30 seconds work and 30 seconds relief, oxygen consumption was similar to that of continuous exercise of the same average power output.



According to Saltin et al. (84) during intermittent exercise with a work interval of less than 60 seconds and a relief interval in the range of 1:1, oxygen consumption should oscillate only slightly around the requirements of average power output.

Essen (33) reported that an interval schedule of 15 seconds of work and 15 seconds of relief resulted in a similar heartrate from work to rest and that this heartrate was similar to the heartrate observed during continuous exercise of the same average power output.

Thus far the literature reviewed here has discussed only the acute responses of interval work compared with continuous work. A further examination of the literature has demonstrated that interval training programs do produce significant improvements in aerobic power. (24,31,36, 37,38,57)

Fox et al. (37) examined the effects of different interval running distances on aerobic power. Subjects trained five days per week for 7.5 weeks at a work:relief ratio of 1:3. Significant increases in aerobic power were observed in each training group with no significant between group differences.

Knuttgen et al. (57) also examined the effects on aerobic power of training with intervals of different lengths. Subjects were randomly assigned to one of three groups. The first group worked for 15 seconds while the second group worked for three minutes. The relief interval was the same length as the work interval for each group. Subjects trained between ten and 15 minutes, three days per week for eight weeks. Both groups experienced a significant increase in aerobic power. The short interval group experienced an increase of 13.2 per cent while the long



interval group experienced an increase of 18 per cent. There was also a significant between group difference. Knuttgen et al. (57) also found that gains in aerobic power were inversely related to initial aerobic power measurements.

Eddy et al. (31) compared the effects of interval and continuous training, over a 12 week period, in both men and women. Both types of training produced almost identical increases in aerobic power when the total workload was equated for each training session. Increases in aerobic power were in excess of 20 per cent and the response in both males and females was of the same magnitude and in the same direction.

The cardiovascular response of women to interval vs. continuous training was further examined by Cunningham et al. (24) Significant increases in aerobic power, in excess of 18 per cent, were reported for both training groups as compared to a control group. However, there was no significant difference between training groups.

Thus, there is evidence to suggest that an interval training program can be a viable alternative to continuous training for the purpose of increasing aerobic power.

### Considerations in Developing an Aerobic Training Program

Prior to designing any aerobic training program, interval or continuous, it is important to take into consideration the training variables which will effect the program.

The key variable we must consider is the intensity of the work to be done by the participants. When using an interval training program the work intensity must be sufficient to produce an average power output that





will result in an oxygen consumption high enough to result in an increase in aerobic power (4,24,29,59). Since it is not practical to directly monitor oxygen consumption during training sessions, training heartrates should be monitored to ensure that they are within the appropriate target zone considered necessary to facilitate improvement in cardiovascular function. (6,39) Although this "threshold intensity" (29) varies from individual to individual it has generally been suggested that individuals should train at a heartrate between 60% and 85% of their maximum heartrate, as estimated according to their age. (6,24,31,39,85,95) The initial percentage chosen by various researchers varies with the characteristics of subjects and depends primarily on initial fitness levels and age. (6,39,85)

Another important consideration when designing an aerobic training program is the duration of each session. The minimum duration necessary for each training session is still controversial. (39,85) A minimum of 20 minutes of continuous exercise is often recommended. (72) However, "most North American authors regard a minimum duration of 30 minutes as more appropriate." (85:230)

With regards to interval training the total duration of each session is often the same, however, the total duration of work amounts to approximately half that of the workout, depending upon the work:relief ratio. (18,27,29)

The next consideration is to establish the frequency of training. Many researchers have subjects train four times per week (24,31,38) and four or five times are most often recommended. (85) However, there is still some controversy as to the minimum number of session per week required to produce changes in aerobic power.





Astrand and Rodahl (6:409) suggest that "for an untrained individual an exercise that demands an oxygen uptake exceeding 50 per cent of his or her maximal will, when repeated two or three half hours a week gradually increase the maximal oxygen uptake."

In the case of interval training, Pollock et al. (75) reported significant gains in aerobic power for each of two groups; one which trained two times per week and one which trained four times per week. Over a period of 20 weeks the group who trained four times per week had significantly greater gains in aerobic power over the group who trained two times per week. However, it is interesting to note that after ten weeks of training, although both groups had significant gains in aerobic power, there was no significant difference between the two groups at this stage.

Contrary to these findings, Fox et al. (36) found that frequencies between two and five days per week over periods of seven to 13 weeks did not significantly affect gains in aerobic power. However, in the study by Gettman et al. (41) the frequency of circuit weight training was three times per week and significant increases in aerobic power were reported after 12 weeks of training.

Thus, the literature with regards to the necessary frequency of training also remains controversial. Although it is generally recommended that individuals train four or five times per week (85) it seems that two or three times per week is adequate providing the intensity of the program is sufficient. (6,36,38,41)

In research, consideration must also be given to duration of time over which subjects trained before the training benefits were assessed.



Much of the early research examined changes over a period of four to eight weeks and it is suggested that perhaps this is not sufficient enough time to allow for major increases in aerobic power, particularly if the frequency of the training sessions is minimal. (36,38,39,75)

More recent research studies tend to observe aerobic training effects over a period of 12 weeks, (24,31,41) although no optimal period of time has yet been established in the literature. Significant increases in aerobic power have been reported over time periods anywhere from seven weeks (95) to 20 weeks (75) and the magnitude of change varies with the intensity and the frequency of training. (24,31,36,95)

### Measuring Aerobic Power

Interest in measuring aerobic power dates back to the work of Hill et al. (15) Since this time a great deal of practical and theoretical knowledge has been accumulated and many methods for assessing  $\dot{V}O_{2\max}$  have been developed and recorded in the literature. (5,8,65,91,99) However, these techniques require complicated apparatus and require maximum effort from subjects. Demanding maximal effort from individuals can present motivational problems since two or three measurements of oxygen consumption are required above the level at which maximum oxygen intake occurs in order to obtain a reliable estimate of maximum oxygen uptake. (100) Further, the health risks involved with subjecting relatively unfit individuals, particularly those over 30, to maximal effort exercise are of major concern. (27,100)

With these problems in mind, exercise physiologists endeavored to develop a submaximal test which would give a reliable and accurate estimate of an individual's true maximum oxygen uptake. A number of submaximal





tests have been developed (1,45,88,94) based on the linear relationship observed between heartrate and oxygen consumption. On the basis of this oxygen-heartrate relationship it is possible to predict an individual's maximum oxygen uptake by the heartrate response to two submaximal workloads, assuming a maximal heartrate of approximately 190 to 200 beats per minute. (6) However, since maximal heartrate declines with age, it is necessary to make corrections for age. These considerations formed the basis for the nomogram by Astrand and Rhyming (1) which was modified by I. Astrand (4) to include an age correction factor. This nomogram has been used extensively over the years and has provided reasonably accurate predictions of maximal oxygen uptake. (4,29,45,94) The standard error of estimate ranges from approximately 7% (29) in relatively well-trained individuals of the same age up to 15% for moderately trained individuals of varying ages. (4)

Every researcher must be aware of the limitations of submaximal predictive tests and should evaluate the usefulness of such tests accordingly. Astrand and Rodahl (6:355) suggest that "the submaximal exercise test is a very useful tool in evaluating whether or not a training program has been effective in improving the individual's circulatory capacity."

### Techniques for Assessing Body Composition

Many techniques are available for assessing the fat and lean components of the body. (14) Two of the most familiar techniques used are hydrostatic weighing and anthropometric measures.

Hydrostatic weighing is based on the principal of Archimedes, and the volume of the body is determined from its displacement of water. (87)





In order to eliminate the volume of the air in the lungs the gross volume of the body must be corrected for residual air volume in the lungs. "The density of the whole body is simply the total weight in air divided by the total body volume as estimated by hydrostatic weighing." (54:267) Since the density of fat is less than that of the other body components such as bone and muscle, the lower the density the greater the proportion of fat. Therefore, hydrostatic weighing is used to estimate body density which is substituted into a formula for determining per cent body fat.

Hydrostatic weighing is considered to be one of the more valid indirect techniques available for assessing body composition, with an error of estimate of approximately three to four per cent. (15,87) However, validation of this technique has been accomplished primarily through research with animals (54,78) and through analysis of a very limited number of human cadavers. (54) The question of validity of assessing human body composition indirectly has only been dealt with on occasion (14,54,87) and "there is probably little one can do to improve the situation except to acknowledge there are some limitations and unavoidable constraints and assumptions one must contend with." (51:250)

There are also a number of sources of measurement error associated with hydrostatic weighing. (15,50,52,54) In order to limit measurement error it becomes important to do repeated measurements on subjects due to an apparent practice effect in achieving a true underwater weight score. (50) However, repeated measurements of underwater weighing become very time consuming and inconvenient to subjects. Further, the necessary equipment for hydrostatic weighing is not readily available. Therefore, many researchers have chosen to use anthropometric measurements for



assessing body composition. These measurements are most often used in a regression equation to determine body density, which is in turn substituted into a formula to determine per cent body fat. However, there are a great number of regression equations which have been developed to predict body density from skinfold measurements, from girth measurements and from a combination of both types of measurements. (30,49,50,51,89) The assumption upon which such measurements are based is that 50 per cent of the body's fat is deposited subcutaneously. (54) Most of these regression equations which have been developed have been validated by correlating body density prediction efficiency with measurements using hydrostatic weighing. Correlations reported in the literature vary from .85 to .87 when male subjects were used, (12,49,51,71,97) while somewhat lower correlations ranging from .70 to .78 have been reported for female subjects. (49,51,89,98,101)

Some measurement sites are better predictors than others and skinfold measurements are generally better predictors than girth measurements. (49, 51) The sites which tend to predict more efficiently are the triceps, iliac crest and subscapular. (49,51,89) The juxtaniipple site is also an effective predictor in males. (51,71) Katch (52) suggests that as a minimum number, the skinfold sites which are most useful are the triceps, subscapular and iliac crest. Thus, when selecting a prediction equation to use, researchers must keep in mind the most efficient prediction sites for measurement. It is also important to consider sites which provide ease of measurement to reduce tester error. The tester must also allow for considerable practice in order to establish test-retest reliability and a minimum of two measurements should always be taken. (52)



## CHAPTER III

### METHODS AND PROCEDURES

#### Sample Selection

The sample consisted of 70 volunteer subjects, both male and female, who were medically screened using the Par-Q questionnaire. (18)

Subjects who volunteered to participate in the training program were asked to find an individual willing to participate in the control group. The individual they chose was to be as similar to them as possible with regards to age, stature, weight and activity patterns. The selection of control subjects in this manner was an attempt to match the two groups in an effort to limit some of the bias introduced when volunteers are used in a study.

The training group initially consisted of 19 females and 22 males while the control group consisted of 13 females and 16 males. However, during the course of the training program three females and two males dropped out of the training group leaving 16 females and 20 males in this group.

#### Testing

Testing procedures consisted of a pre-test, administered within two weeks prior to the start of training and a post-test, administered within two weeks of completion of training. All subjects were required to sign a consent form prior to having each test administered.

In order to ensure that everyone was aware of factors which might bias test results, a list of instructions was distributed to all sub-





jects prior to any testing.

When subjects arrived to be tested they were weighed using a physician's scale calibrated in kilograms. All subjects were weighed without shoes and while wearing gymnasium apparel.

### Body Fat

Skinfolds were measured and per cent body fat was determined based on the mean of calculations using two different methods.

The first method used was that described by Durnin and Rahaman. (30) The regression equations for the estimation of body density (Y) from the log of the sum of four skinfold thicknesses in mm.(X) were:

$$\text{Men: } Y = 1.1610 - .0632X$$

$$\text{Women: } Y = 1.1581 - .0720X$$

The four skinfold measurements taken were the triceps, biceps, subscapula and suprailiac.

The values determined for body density were then substituted into the Siri equation (62) to estimate per cent body fat. This equation was:

$$\% \text{ Fat} = [ (4.95/Y) - 4.5 ] \times 100$$

The second method used for men was described by Pascale. (71) The regression equation used to determine body density (D) from three skinfold thicknesses in mm. ( $X_1, X_2, X_3$ ) was:

$$D = 1.088468 - [.0007123 (X_1) + .004832 (X_2) + .0005513 (X_3)]$$

The three skinfold measurements taken were the triceps, juxt nipple and midaxillary line.

The second method used for women was that described by Sloan et al. (89) The regression equation used to determine body density (D) from two





skinfold measurements in mm.  $(X_1, X_2)$  was:

$$D = 1.0764 - [.00081 (X_1) + .00088 (X_2)]$$

The skinfold measurements taken were the triceps and the supra-iliac.

The values determined for body density for both men and women, were then substituted into the Brozek and Keys equation (15) to estimate per cent body fat. This equation was:

$$\% \text{ Fat} = [4.570/D - 4.142] \times 100$$

All skinfold measurements were taken on the right side of the body with the subjects standing relaxed and erect. Two measurements were taken at each site and if they were less than or equal to one mm. apart the average of the two was recorded. If the two measurements were more than a mm. apart a third measurement was taken and the average of the two closest measurements was recorded. The caliper dial was read when the indicator came to a relative stop after the initial quick movement. Measurements were taken at each site according to the following technique.

**Triceps** - The caliper was applied over the midpoint of the muscle belly, midway between the tip of the acromion and the olecranon process with the arm hanging relaxed and vertical. The jaws of the caliper were placed in the vertical plane.

**Biceps** - The calipers were applied in the vertical plane over the muscle belly, with the arm hanging relaxed and vertical.

**Subscapular** - The caliper was applied immediately below the tip of the inferior angle of the scapula at approximately a 45 degree angle to the vertical plane.

**Suprailiac** - The caliper was applied approximately three cm. above



the iliac crest at an angle along the line of the crest.

Juxt nipple - The caliper was applied just above the nipple, along the line of Linn.

Midaxillary - The caliper was applied, in the vertical plan, along the midaxillary line of the body, at the level of the xiphoid process.

In all cases the skin and subcutaneous fat were firmly grasped between the left thumb and forefinger and pulled up and away from any underlying tissues. The caliper jaws were placed approximately one cm. below the fingers.

#### Eight Minute Bicycle Ergometer Test

This test was performed in order to estimate maximal oxygen consumption. (6) The test involved riding the bicycle ergometer continuously for eight minutes at a constant rate of 60 revolutions per minute. A metronome was used to help subjects keep the correct cadence.

During the first four minutes the workload was set primarily to provide the subject with a warm-up and to give the tester an indication of what level to set the workload at for the final four minutes. Following the initial four minutes the workload was increased to a level that the tester felt would evoke a steady state heartrate of approximately 70% to 80% of each subject's estimated maximum heartrate ( $220 - \text{age}$ ). An exersentry was used to moniter heartrate throughout the eight minutes of the test.

The seat of the bicycle ergometer was adjusted according to each subject's height such that the leg was almost fully extended when the pedal was in the lowest position.



The total amount of work accomplished was calculated by multiplying the load setting times the number of revolutions per minute. It was assumed that all subjects kept cadence with the metronome.

Maximal oxygen consumption was then estimated using the Astrand-Rhyming Nomogram. (1) Using this nomogram an absolute value of oxygen consumption expressed in litres per minute was attained for each subject. This value was then multiplied by an age correction factor (2) and converted to a relative value of oxygen consumption using Astrand's (2) tables. This value was expressed in millilitres per kilogram of body weight per minute.

### Training Program

The training program consisted of a circuit of ten exercises using various Hydra-Gym machines. The following stations were included in the program and whenever possible were performed in the order listed:

(See Appendix A)

1. Power Squat (legs)
2. Bench Press
3. Pro Power (legs)
4. Power Butterfly
5. Power Runner (legs)
6. Shoulder Press
7. Uni-Lateral Knee (legs)
8. Arm Curls
9. Sit-Ups
10. Abductor-Adductor (legs)





Exercises were arranged in this manner so as to alternate leg and arm exercises. This order was followed to prevent excessive local muscular fatigue which might prevent subjects from continuing the work-out at a rate that would have a greater influence on their overall cardiovascular response.

For each exercise, subjects performed as many repetitions as possible in 20 seconds, followed by a 40 second relief interval, during which each individual moved to the next station.

All subjects started the program by completing two circuits of the exercises and progressed to three complete circuits within the first two weeks of the program.

During the first four weeks of the program the work:relief ratio remained at 20:40. From the fifth week on, the rest interval was gradually reduced and the work time gradually increased such that the work:relief ratio was 23:32 at the end of ten weeks when the program was completed.

### Statistical Analysis

A three way analysis of variance was employed to analyze the data from this study. Four individual analyses were run through computer facilities at the University of Alberta using the SPSS batch system. The following classification variables were involved in the analyses:

1. Treatment - control or training
2. Sex - male or female
3. Age level - young or old
4. Initial  $\text{VO}_2\text{max}$  - high or low
5. Initial per cent body fat - high or low



The dichotomy of the first two variables is obvious. The age criterion for the age level dichotomy was 35 years. Anyone less than 35 was classified as young and the rest as old. Initial  $\text{VO}_2\text{max}$  was based on predicted values attained in the pre-test and subjects were classified as high or low according to population norms for their particular sex and age group. (90) Initial per cent body fat was also based on predicted values attained from the pre-test and subjects were classified as high or low according to the median of the group as a whole.

The dependent variable in the first two analyses was post-test  $\text{VO}_2\text{max}$ . The classification variables used in the first of these analyses were treatment, sex, and initial  $\text{VO}_2\text{max}$ . In the second of these analyses age level was substituted for sex, while the other two variables remained the same.

The dependent variable in the second two analyses was post-test per cent body fat. The classification variables for the first of these analyses were treatment, sex and initial per cent body fat. In the second analyses the age level variable was again substituted for sex while the other two variables remained the same.

T-Tests were also done to determine the level of significance between the means of the following groups for pre-test  $\text{VO}_2\text{max}$  and per cent body fat:

1. training and control
2. male and female
3. old and young
4. high and low

The level of significance for this analysis was also set at .05.



As a test of reliability, a Spearman Rho correlation coefficient was calculated between pre and post measures for  $\text{VO}_2\text{max}$  and per cent body fat using the data for the control group.





# CHAPTER IV

## RESULTS AND DISCUSSIONS

### Results

A summary of the results of the first three way analysis on post-test  $VO_2\text{max}$  are presented in TABLE I. The main effects were significant at the .05 level of significance, as were the effects of treatment, sex and initial  $VO_2\text{max}$ . There was no significant interaction between these factors.

A summary of the second three way analysis on post-test  $VO_2\text{max}$ , in which age level was substituted for sex, is presented in TABLE II. Again the main effects were significant at the .05 level of significance. The effects of treatment, age level and initial  $VO_2\text{max}$  were also significant and there was no significant interaction between any of these factors.

TABLE I

SUMMARY OF THREE WAY ANALYSIS OF VARIANCE ON POST-TEST  $VO_2\text{MAX}$  - FACTORS: TREATMENT, SEX, INITIAL  $VO_2\text{MAX}$

| Source of Variation      | Degrees of Freedom | Mean Square | F Ratio | Critical F |
|--------------------------|--------------------|-------------|---------|------------|
| Main Effects             | 3                  | 734.012     | 14.908  | 2.75       |
| Treatment                | 1                  | 655.879     | 13.321  | 3.99       |
| Sex                      | 1                  | 433.452     | 8.803   | 3.99       |
| Initial $VO_2\text{max}$ | 1                  | 1467.774    | 29.811  | 3.99       |
| Error Term               | 57                 | 49.237      |         |            |



TABLE II

SUMMARY OF THREE WAY ANALYSIS OF VARIANCE ON  
POST-TEST  $VO_2$ MAX - FACTORS: TREATMENT, AGE LEVEL, INITIAL  $VO_2$ MAX

| Source of Variation | Degrees of Freedom | Mean Square | F Ratio | Critical F |
|---------------------|--------------------|-------------|---------|------------|
| Main Effects        | 3                  | 758.642     | 16.009  | 2.75       |
| Treatment           | 1                  | 891.214     | 18.806  | 3.99       |
| Age Level           | 1                  | 507.342     | 10.706  | 3.99       |
| Initial $VO_2$ MAX  | 1                  | 805.254     | 16.993  | 3.99       |
| Error Term          | 57                 | 47.389      |         |            |

The significant effects between age groups, sexes and initial  $VO_2$ max were expected. The results of T-tests, as shown in TABLE III, demonstrated a significant difference between these groups as a result of the pre-test. Since the initial  $VO_2$ max groups were based on pre-test measures the relationship between these groups was expected to remain unchanged. Further, the difference between  $VO_2$ max values for males and females is well documented (2,6,31,39) as is the steady decline in  $VO_2$ max with increasing age (2,6,39,90) and since there was a significant difference between the groups as a result of the pre-test, this relationship was expected to remain unchanged.

However, there was no significant difference between the training and control groups initially. An examination of the group means, as shown in TABLE IV and TABLE V, indicated that the training group experienced an 11.90 per cent increase in  $VO_2$ max. These findings are graphically represented in FIGURE I.



TABLE III  
SUMMARY OF T-TESTS ON PRE-TEST VO<sub>2</sub>MAX

| Group                       | Degrees of Freedom | Variance Estimate | T Ratio | Critical T |
|-----------------------------|--------------------|-------------------|---------|------------|
| Treatment                   | 63                 | 1.15              | 1.90    | 2.00       |
| Sex                         | 63                 | 2.17              | 7.00    | 2.00       |
| Age Level                   | 63                 | 1.27              | 29.01   | 2.00       |
| Initial VO <sub>2</sub> max | 63                 | 49.39             | 4.97    | 2.00       |

TABLE IV  
PRE-TEST GROUP MEANS FOR PREDICTED VO<sub>2</sub>MAX (ml/kg/min)

| Factor                      | Group    | N  | Pre-Test $\bar{x}$ | Standard Deviation |
|-----------------------------|----------|----|--------------------|--------------------|
| Treatment                   | Training | 36 | 35.73              | 10.34              |
|                             | Control  | 29 | 36.24              | 8.53               |
| Sex                         | Male     | 36 | 37.24              | 9.18               |
|                             | Female   | 29 | 34.73              | 7.66               |
| Age Level                   | Young    | 44 | 39.00              | 7.46               |
|                             | Old      | 21 | 30.28              | 8.82               |
| Initial VO <sub>2</sub> max | High     | 20 | 43.89              | 6.14               |
|                             | Low      | 45 | 32.28              | 7.53               |





TABLE V  
POST-TEST GROUP MEANS FOR PREDICTED  $\text{VO}_2\text{MAX}$  (ml/kg/min)

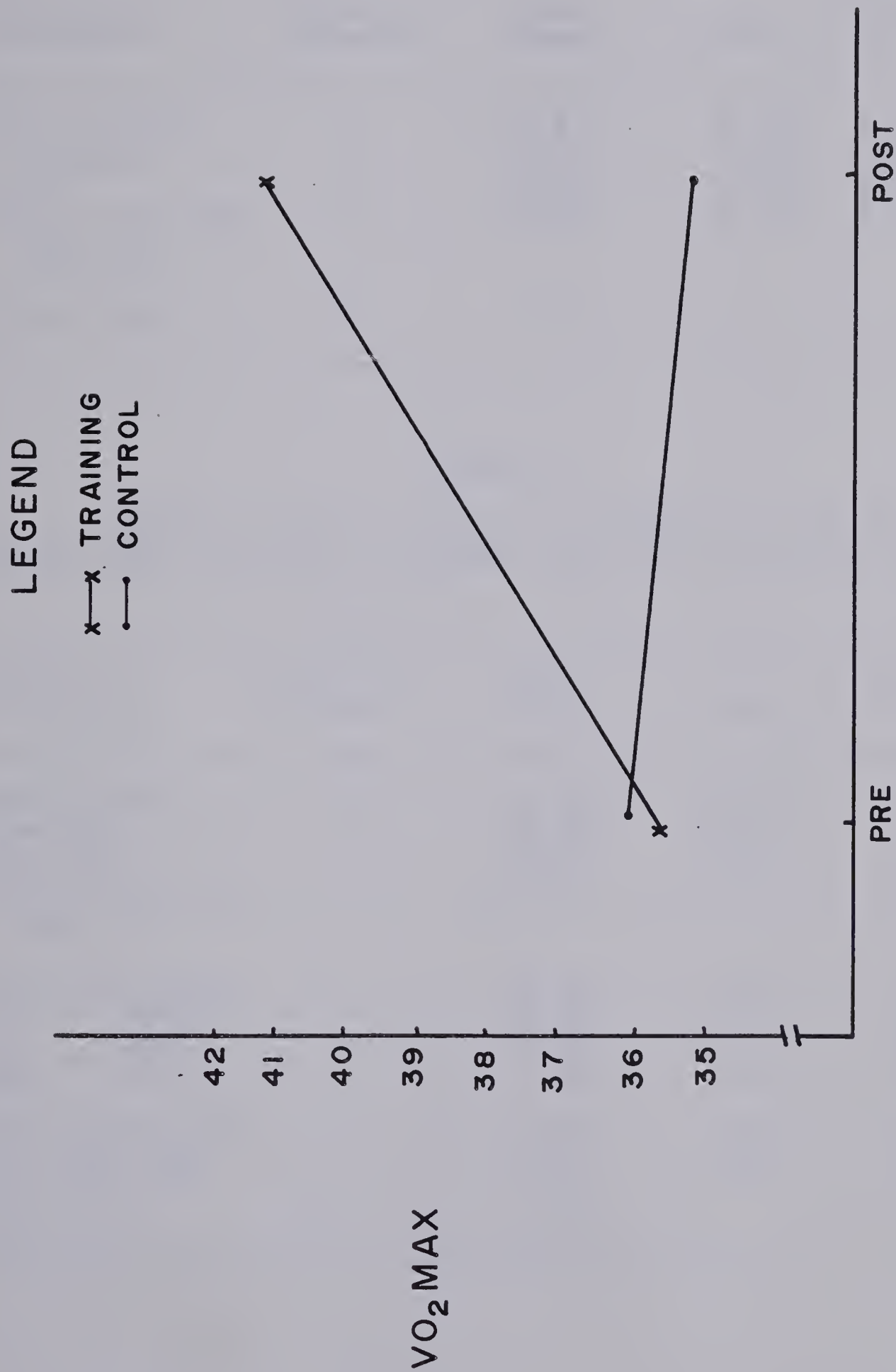
| Factor                          | Group    | N  | Post-Test<br>$\bar{x}$ | Standard<br>Deviation |
|---------------------------------|----------|----|------------------------|-----------------------|
| Treatment                       | Training | 36 | 41.12                  | 8.87                  |
|                                 | Control  | 29 | 35.12                  | 7.95                  |
| Sex                             | Male     | 36 | 39.16                  | 9.41                  |
|                                 | Female   | 29 | 36.65                  | 8.18                  |
| Age Level                       | Young    | 44 | 40.61                  | 8.58                  |
|                                 | Old      | 21 | 34.38                  | 8.37                  |
| Initial $\text{VO}_2\text{max}$ | High     | 20 | 45.05                  | 7.00                  |
|                                 | Low      | 45 | 35.93                  | 8.33                  |

A summary of the results of the first three way analysis of variance on post-test per cent body fat are presented in TABLE VI. The main effects were significant at the .05 level of significance, as were the effects of treatment, sex and initial per cent body fat. There was no significant interaction between any of these factors.

A summary of the second three way analysis on post-test per cent body fat, in which age level was substituted for sex, is presented in TABLE VII. Again the main effects were significant. Treatment, age level and initial  $\text{VO}_2\text{max}$  effects were also significant at the .05 level.

Again, the significant differences between sex, age level and initial per cent body fat were expected. Results of T-tests, as shown in TABLE VIII, demonstrated a significant difference between these group means based on the pre-test. Since the initial per cent body fat groups were based on pre-test measures, the relationship between these groups





TESTING SESSION

FIGURE I. GROUP MEANS FOR PREDICTED VO<sub>2</sub> MAX (ml/kg/min)



TABLE VI

SUMMARY OF THREE WAY ANALYSIS ON POST-TEST PER CENT BODY FAT -  
FACTORS: TREATMENT, SEX AND INITIAL PER CENT BODY FAT

| Source of Variation       | Degrees of Freedom | Mean Square | F Ratio | Critical F |
|---------------------------|--------------------|-------------|---------|------------|
| Main Effects              | 3                  | 470.435     | 34.914  | 2.75       |
| Treatment                 | 1                  | 85.464      | 6.343   | 3.99       |
| Sex                       | 1                  | 110.664     | 8.213   | 3.99       |
| Initial Per Cent Body Fat | 1                  | 373.669     | 27.737  | 3.99       |
| Error Term                | 57                 | 13.474      |         |            |

TABLE VII

SUMMARY OF THREE WAY ANALYSIS OF VARIANCE ON POST-TEST  
PER CENT BODY FAT-FACTORS: TREATMENT, AGE LEVEL AND INITIAL PER CENT FAT

| Source of Variation       | Degrees of Freedom | Mean Square | F Ratio | Critical F |
|---------------------------|--------------------|-------------|---------|------------|
| Main Effects              | 3                  | 473.152     | 41.340  | 2.75       |
| Treatment                 | 1                  | 150.469     | 13.147  | 3.99       |
| Age Level                 | 1                  | 118.814     | 10.381  | 3.99       |
| Initial Per Cent Body Fat | 1                  | 1277.051    | 111.577 | 3.99       |
| 2 way Interactions        | 3                  | 23.143      | 2.022   | 2.75       |
| Tr Aged                   | 1                  | 31.724      | 2.772   | 3.99       |
| Tr BFPR                   | 1                  | 45.886      | 4.009   | 3.99       |
| Aged BFPR                 | 1                  | 1.129       | .099    | 3.99       |
| 3 way Interactions        | 1                  | 53.197      | 4.648   | 3.99       |
| Tr Aged BFPR              | 1                  | 53.197      | 4.648   | 3.99       |
| Error Term                | 57                 | 11.445      |         |            |





was expected to remain unchanged. Again, as with  $VO_2$ max values, the difference between males and females with respect to body fat is well documented. (6,39,51,90) The tendency for individuals to increase fat deposition as age increases is also well documented. (6,13,39,90) Therefore, since the pre-test demonstrated a significant difference, it was expected that this relationship would remain the same for the post-test.

However, there was no significant difference between the training and control groups as a result of the pre-test but the post-test differences were significant.

TABLE VIII  
SUMMARY OF T-TESTS ON PRE-TEST PER CENT  
BODY FAT

| Group                     | Degrees of Freedom | Variance Estimate | T Ratio | Critical T |
|---------------------------|--------------------|-------------------|---------|------------|
| Treatment                 | 63                 | 36.23             | .13     | 2.00       |
| Sex                       | 63                 | 16.55             | 7.81    | 2.00       |
| Age Level                 | 63                 | 22.71             | 2.58    | 2.00       |
| Initial Per Cent Body Fat | 63                 | 14.40             | 9.84    | 2.00       |

An examination of the pre-test and post-test means for these groups, as presented in TABLE IX and TABLE X, revealed that the training group had an absolute decrease of 1.87 per cent body fat. This absolute decrease represents a relative decrease in body fat of 8.1 per cent. The group means are graphically illustrated in FIGURE II.



TABLE IX  
PRE-TEST GROUP MEANS FOR PER CENT BODY FAT

| Factor                       | Group    | N  | Pre-Test<br>$\bar{x}$ | Standard<br>Deviation |
|------------------------------|----------|----|-----------------------|-----------------------|
| Treatment                    | Training | 36 | 21.31                 | 5.71                  |
|                              | Control  | 29 | 21.37                 | 6.36                  |
| Sex                          | Male     | 36 | 17.36                 | 4.22                  |
|                              | Female   | 29 | 25.35                 | 4.74                  |
| Age Level                    | Young    | 44 | 19.95                 | 5.52                  |
|                              | Old      | 21 | 22.70                 | 6.26                  |
| Initial Per Cent<br>Body Fat | High     | 32 | 25.61                 | 4.37                  |
|                              | Low      | 33 | 16.36                 | 3.24                  |

TABLE X  
POST-TEST GROUP MEANS FOR PER CENT BODY FAT

| Factor                       | Group    | N  | Post-Test<br>$\bar{x}$ | Standard<br>Deviation |
|------------------------------|----------|----|------------------------|-----------------------|
| Treatment                    | Training | 36 | 19.30                  | 5.36                  |
|                              | Control  | 29 | 21.12                  | 6.37                  |
| Sex                          | Male     | 36 | 16.62                  | 4.11                  |
|                              | Female   | 29 | 24.45                  | 4.70                  |
| Age Level                    | Young    | 44 | 19.46                  | 5.80                  |
|                              | Old      | 21 | 21.47                  | 5.89                  |
| Initial Per Cent<br>Body Fat | High     | 32 | 24.48                  | 4.61                  |
|                              | Low      | 33 | 15.88                  | 3.25                  |



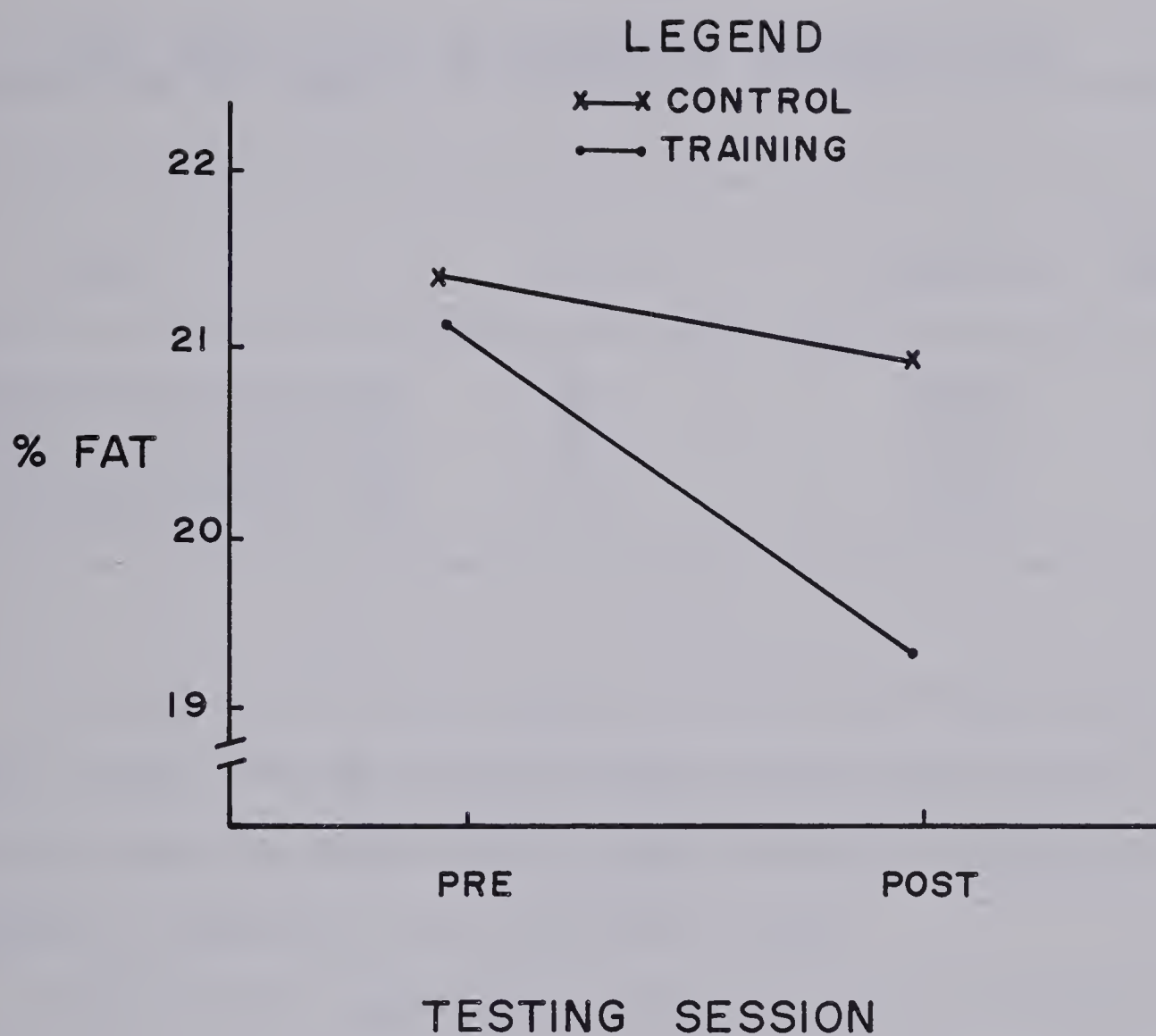


FIGURE II. GROUP MEANS FOR PER CENT  
BODY FAT



The second analysis of variance on post-test per cent body fat also revealed a significant interaction between initial per cent body fat and treatment. (See TABLE VII) The group means for these interacting variables are presented in TABLE XI and are graphically represented in FIGURE III.

TABLE XI

GROUP MEANS FOR THE TWO INTERACTING VARIABLES IN THE SECOND THREE WAY ANALYSIS OF VARIANCE ON POST-TEST PER CENT BODY FAT

| Group                   | N  | $\bar{x}$<br>Post-Test | Standard<br>Deviation |
|-------------------------|----|------------------------|-----------------------|
| Control/Initially High  | 13 | 26.57                  | 4.62                  |
| Control/Initially Low   | 16 | 16.70                  | 4.08                  |
| Training/Initially High | 19 | 23.05                  | 3.84                  |
| Training/Initially Low  | 17 | 15.12                  | 3.88                  |

An examination of group means indicates that those individuals who were involved with the training program and who were initially high in per cent body fat demonstrated a greater reduction in body fat. This finding is supported in the literature. (6,39)

There was also significant interaction between all three factors. The group means for the interacting factors are presented in TABLE XII.

An examination of these group means indicate that all the training groups had considerably lower values than the corresponding control groups and that the old training groups demonstrated greater differences between corresponding control groups than did corresponding young training groups when compared to the appropriate control group. These differences are best illustrated in FIGURE IV. Further observations of the group means





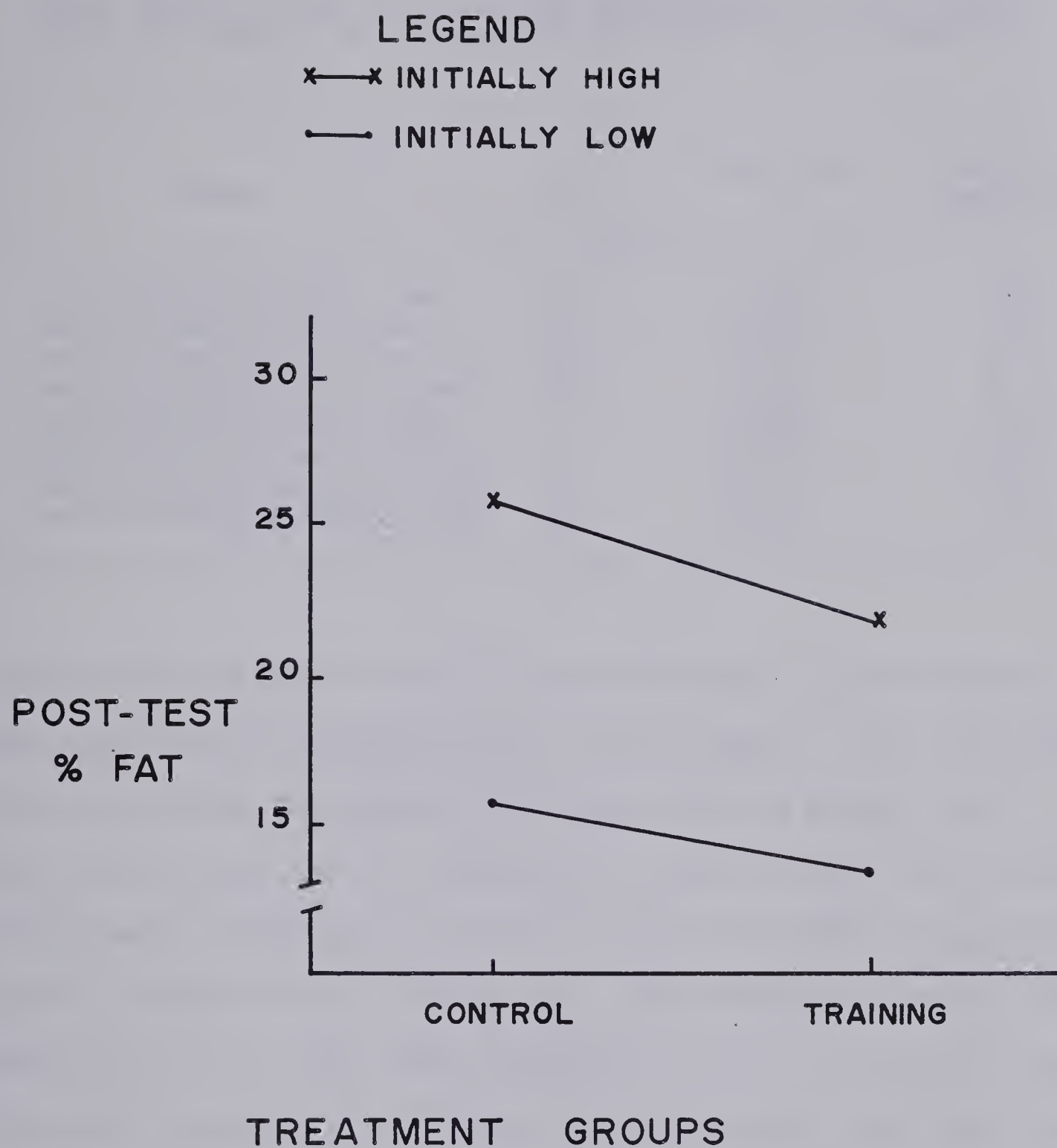


FIGURE III. GROUP MEANS FOR INTERACTING  
VARIABLES-TREATMENT AND INITIAL  
PER CENT BODY FAT



TABLE XII

GROUP MEANS FOR THE THREE INTERACTING VARIABLES IN THE SECOND  
THREE WAY ANALYSIS OF VARIANCE ON POST-TEST PER CENT BODY FAT

| Group                         | N  | Post-Test<br>$\bar{x}$ | Standard<br>Deviation |
|-------------------------------|----|------------------------|-----------------------|
| Training/Old/Initially Low    | 8  | 17.85                  | 1.98                  |
| Control/Old/Initially Low     | 4  | 20.04                  | 1.07                  |
| Training/Young/Initially Low  | 10 | 13.04                  | 2.44                  |
| Control/Young/Initially Low   | 10 | 14.91                  | 2.72                  |
| Training/Old/Initially High   | 7  | 24.88                  | 5.09                  |
| Control/Old/Initially High    | 2  | 28.26                  | 13.00                 |
| Training/Young/Initially High | 11 | 22.15                  | 2.31                  |
| Control/Young/Initially High  | 13 | 25.13                  | 3.06                  |

indicate that the means of the old training groups are considerably higher than the corresponding young training groups. This relationship primarily explains the greater differences observed between the old training groups and the corresponding old control groups since individuals who were initially high in per cent body fat tended to experience greater decreases in per cent body fat. This tendency is obvious from observations of the group means presented in TABLE XI as well as from the significant two-way interaction between treatment and initial per cent body fat as illustrated in FIGURE III. This observation is also supported in the literature. (6,39) However, it should be noted that the significant three-way interaction observed in this analysis may be somewhat biased by the discrepancy in cell numbers for the different groups since there were considerably fewer old subjects.

Finally, reliability coefficients of .98 and .90 were calculated for per cent body fat and predicted  $\text{VO}_{2\text{max}}$ , respectively.



1 cm = 1% BODY FAT

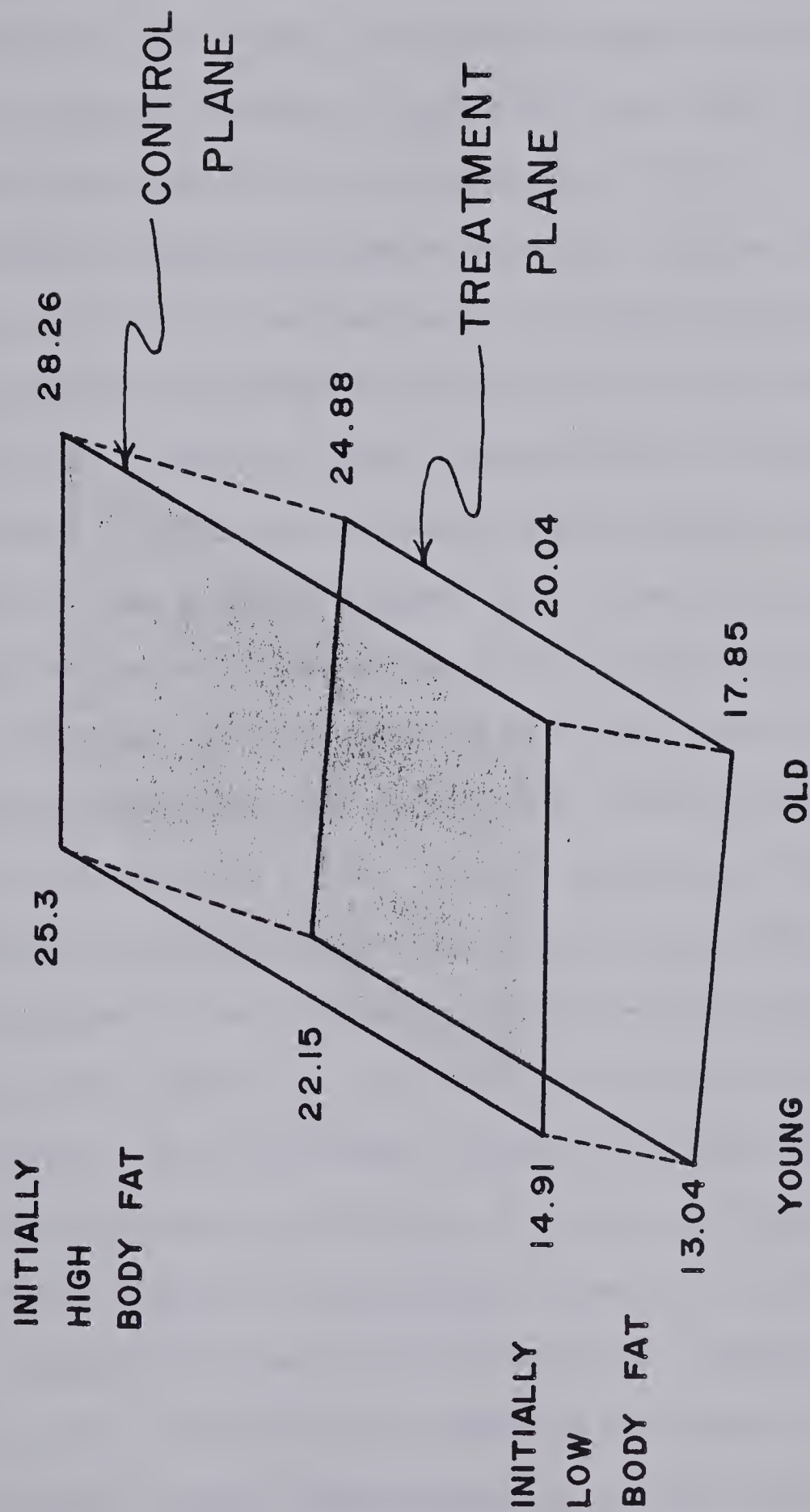


FIGURE IV. GROUP MEANS FOR INTERACTING VARIABLES -  
TREATMENT, AGE AND INITIAL BODY FAT





## Discussion

### Aerobic Power

The results of the present study indicate that the training group experienced an overall increase in  $\dot{V}O_{2\max}$  of 12 per cent. These findings are consistent with those of Gettman et al. (41)

The evidence of these two studies strongly indicate that aerobic power can be significantly improved using variable resistance exercise equipment, provided the appropriate work protocol is utilized. However, the results of the present study were achieved over a shorter time period. The work interval used in the present study was also shorter than that used in the study by Gettman et al. One of the major reasons for this observation may be due to the nature of hydraulic resistive equipment. Since most of this apparatus works both agonistic and antagonistic muscles during the same exercise set, an individual can accomplish more work in a shorter time frame. Further, due to the rhythmic pumping of blood through the muscles, there may be less local fatigue which would allow the individual to work harder during each work interval.

However, more research is required to substantiate the findings of the present study. One of the major problems associated with comparing the relative effectiveness of different variable resistance exercise systems is the difficulty in equating the intensity of training or the total work accomplished in each training session. Equating the intensity of training is also a problem when attempting to compare the findings of the present study to other studies reporting greater increases in aerobic power but utilizing other modes of exercise. (22,23,24,31,32,34,48)



The three way analyses of variance on post-test  $\text{VO}_2\text{max}$  demonstrated that increases in aerobic power were not influenced significantly by age, sex or initial fitness level.

Sexual differences in  $\text{VO}_2\text{max}$  are well documented. (2,6,39) However, the results of this study suggest that sex does not influence the magnitude of the training effect. This finding is consistent with current literature in this area. (24,31,41)

It is also well documented that as age increases,  $\text{VO}_2\text{max}$  tends to decrease (6,39) however the results presented here indicate that age did not significantly influence the magnitude of the training effect. This finding is in agreement with those of Kasch et al. (48) and Kilbom. (56)

The initial fitness level, based on pre-test  $\text{VO}_2\text{max}$ , did not significantly influence the magnitude of the training effect achieved. This finding is contrary to the literature (6,39,56,57,95). This observation may be largely explained by the small number of fit subjects who were involved in the training group, since only ten of the 36 subjects who trained were initially classed as highly fit. Another factor may have been the degree to which natural endowment was responsible for the  $\text{VO}_2\text{max}$  of those who were classed as highly fit. When compared to population norms some individuals fall into a highly fit category due primarily to genetic endowment, even though they are not regularly involved in physical activity. If this is the case, such individuals may still have the genetic potential to improve considerably when they engage in regular physical activity. (6)

In the present study, two of the subjects, one male and one female, were initially classified as highly fit but still achieved increases in



aerobic power of 19 per cent and 23 per cent, respectively.

### Per Cent Body Fat

The results of the present study also indicated that the training group experienced an absolute decrease of 1.87 per cent body fat which represented a relative decrease of 8.1 per cent. This decrease was in close agreement with the findings of Wilmore (96) but was somewhat less than the decrease reported by Gettman et al. (41). This difference may have been partially due to the shorter training period utilized in the present study. In terms of an absolute decrease in body fat the results presented here are consistent with the findings of Pipes and Wilmore (74) but when compared in terms of relative change, the decrease in body fat in the present study is considerably less. However, when the results of the present study are compared to the results reported by Coleman (22) the decrease in body fat was greater in absolute terms and less in relative terms.

Again, a problem arises when attempting to compare studies reporting changes in body fat since few studies use the same technique or the same formula for determining per cent body fat. However, it is apparent that the training program utilized in this study does decrease body fat significantly.

The three way analyses of variance on post-test per cent body fat revealed that decreased body fat was not significantly influenced by sex or age. However, the initial level of body fat did significantly influence body fat decreases. Those individuals who were initially classified in the high body fat group experienced greater decreases in body fat. These





results are in agreement with the current literature in this area.

(6,21,39)





## CHAPTER V

### SUMMARY AND CONCLUSIONS

#### Purpose

The purpose of the present study was to examine changes in  $VO_2\text{max}$  and per cent body fat as a result of a resistance training program utilizing Hydra-Gym equipment.

#### Sample Selection

Subjects for the training group and the control group were selected on a volunteer basis. An effort was made to match the two groups in order to limit the bias associated with using volunteer subjects.

#### Procedures

Subjects from both groups were tested prior to the start of the program and again immediately following the completion of the training program.

$VO_2\text{max}$  was estimated from two submaximal workloads based on the nomogram of Astrand and Rhymin. (1) Per cent body fat was estimated using the mean value determined from two formulas derived for calculation per cent body fat from various skinfold measurements.

The training program involved omnikinetic training equipment and was based on the principles of interval training. Subjects trained three times per week for ten weeks.

A three way analysis of variance was used to analyze the data. Four individual analyses were obtained; two on post-test  $VO_2\text{max}$  and two on post-test per cent body fat. Four classification variables were involved in each pair of analyses. The classification variables involved in the first



post-test  $\text{VO}_2\text{max}$  analysis were treatment, sex and initial  $\text{VO}_2\text{max}$  level. In the second analysis on post-test  $\text{VO}_2\text{max}$ , age level was substituted for sex. Similarly, in the analyses on post-test per cent body fat the classification variables were treatment, sex and initial per cent body fat. Again, age level was substituted for sex in the second analysis on per cent body fat.

T-tests were calculated on pre-test means of those groups involved in the three way analyses of variance to determine any significant differences between groups prior to the start of the training program.

Reliability coefficients of .98 and .90 were calculated for per cent body fat and predicted  $\text{VO}_2\text{max}$  measures, respectively, using the data for the control group.

## Results

The training group experienced a significant increase of 11.9 per cent in aerobic power. This increase was not significantly influenced by age, sex or initial fitness level.

An absolute decrease of 1.9 per cent body fat was also observed in the training group. In relative terms this represented a decrease of 8.1 per cent. This decrease in body fat was significant at the .05 level.

Age and sex did not significantly affect the observed decrease in body fat. However, the higher body fat group experienced a significantly greater decrease than did the low body fat group.

## Conclusions

From the results of this study, the following conclusions are warranted:



1. Aerobic power can be significantly increased on a training program utilizing hydraulic resistance training equipment.
2. Per cent body fat can be significantly decreased on a training program utilizing the hydraulic resistive equipment.
3. Initial body fat significantly influences the resulting decrease in body fat.





## SELECTED REFERENCES



1. Astrand, P.O. and I. Rhyning, "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate During Submaximal Work", Journal of Applied Physiology 7:218-221, 1954.
2. Astrand, P.O., "Human Physical Fitness with Special Reference to Sex and Age", Physiological Review 36:307, 1956.
3. Astrand, I., P.O. Astrand, E.H. Christensen, and R. Hedman, "Intermittent Muscular Work", Acta Physiologica Scandinavica, 48:448-453, 1960.
4. Astrand, I., "Aerobic Work Capacity in Men and Women with Special Reference to Age", Acta Physiologica Scandinavica Supplement 169:1, 1960.
5. Astrand, P.O. and B. Saltin, "Maximal Oxygen Uptake and Heart rate in Various Types of Muscular Activity", Journal of Applied Physiology 16:153-156, 1961.
6. Astrand, P.O. and K. Rodahl, Textbook of Work Physiology (2nd. ed.) McGraw Hill Book Company, New York, 1977.
7. Bailey, G., "Fit for Anything", British Journal of Sports Medicine, 12:220-222, 1979.
8. Balke, B., "Circulatory Respiratory Response to Physical Work" In: Symposium on Performance Capacity ed. H. Spector, National Research Council, Washington, 1961, p.13.
9. Berger, R.A., "Comparison of Static and Dynamic Strength Increases", Research Quarterly, 33:329-333, 1962.
10. Berger, R.A. and B. Hardage, "Effect of Maximum Loads for Each of Ten Repetitions on Strength Improvement", Research Quarterly, 38:715-718.
11. Brodin, H., "Evaluation of Two Methods for Increasing Muscle Strength", Acta Orthopaedica Scandinavica, 33:208-219, 1963.
12. Brozek, J. and A. Keys, "The Evaluation of Leanness-Fatness in Man, Norms and Interrelationships", British Journal of Nutrition, 5:194-206, 1951.
13. Brozek, J., and A. Keys, "Relative Body Weight, Age and Fatness", Geriatrics, 8:70-75, 1953.
14. Brozek, J., and A. Henschel (Eds.) Techniques for Measuring Body Composition, National Academy of Sciences - National Research Council, Washington, D.C., 1961.



15. Brozek, J., F. Grande, J. Anderson and A. Keys, "Densitometric Analysis of Body Composition: Revision of Some Quantitative Assumptions", Annals of the New York Academy of Science 110:113-140, 1963.
16. Capen, E.K., "The Effect of Systematic Weight Training on Power, Strength and Endurance", Research Quarterly, 21:83-93, 1950.
17. Capen, E.K., "Study of Four Programs of Heavy Resistance Exercises for Development of Strength", Research Quarterly, 27:132-142, 1956.
18. Chisolm D.M., M.L. Collis, L. Kulak, W. Davenport and N. Gruber, "Physical Activity Readiness", British Columbia Medical Journal, 17:375-378, 1975.
19. Chui, E.H., "The Effects of Systematic Weight Training on Athletic Power", Research Quarterly, 21:188-194, 1950.
20. Clarke, D., "Adaptations in Strength and Muscular Endurance Resulting From Exercise", In Wilmore, J. (ed.): Exercise and Sports Sciences Reviews, Vol. 1:73-102, Academic Press; New York, 1973.
21. Clements, E.S., "The Effect of Weight Training on Per Cent of Total Body Fat and the Total Body Weight", Master's Thesis, Pennsylvania State University, 1963.
22. Coleman, A., "Nautilus vs. Universal Gym Strength Training in Adult Males", American Correctional Therapy Journal, 31(4):103-104, 1977.
23. Cotten, D., "Relationship of the Duration of Sustained Voluntary Isometric Contractions to Changes in Endurance and Strength", Research Quarterly, 38:366-374, 1967.
24. Cunningham, D., D. McCrimmon and L.F. Vlach, "Cardiovascular Response to Interval and Continuous Training in Women", European Journal of Applied Physiology, 41:187-197, 1979.
25. Damon, A., and R.F. Goldman, "Predicting Fat from Body Measurements: Densitometric Validation of Ten Anthropometric Equations", Human Biology, 36:32-44, 1964.
26. Darcus, H.D., and N. Salter, "The Effect of Repeated Muscular Exertion on Muscle Strength", Journal of Physiology, 129:325-336, 1955.
27. Davies, C.T.M., "Limitations to the Prediction of Maximum Oxygen Intake from Cardiac Frequency Measurements", Journal of Applied Physiology, 24(5):700-706, 1968.
28. Delorme, T.L., and A.L. Watkins, "Techniques of Progressive Resistance Exercise", Archives of Physical Medicine, 29:263-273, 1948.





29. Devries, H.A., and C.E. Klafs, "Prediction of Maximal Oxygen Intake from Submaximal Tests", Journal of Sports Medicine, 16:207-214, 1963.
30. Durnin, J.V. and M.M. Rahaman, "The Assessment of the Amount of Fat in the Body from Measurements of Skinfold Thickness", British Journal of Nutrition, 21:681-689, 1967.
31. Eddy, D., K. Sparks and D. Adelizi, "The Effects of Continuous and Interval Training in Women and Men", European Journal of Physiology, 41:187-197, 1979.
32. Ekblom, B., P.O. Astrand, B. Saltin, J. Stenberg and B. Wallstrom, "Effect of Training on Circulatory Response to Exercise", Journal of Applied Physiology, 24:518-528, 1968.
33. Essen, B., "Studies on the Regulation of Metabolism in Human Skeletal Muscle Using Intermittent Exercise as an Experimental Model", Acta Physiologica Scandinavica: Suppl. 454, 1978.
34. Fahey, T.D., and C.H. Brown, "The Effect of An Anabolic Steroid on the Strength, Body Composition and Endurance of College Males When Accompanied by a Weight Training Program", Medicine and Science in Sports, 5:272-276, 1973.
35. Ferguson, G.A., Statistical Analysis in Psychology and Education (4th. edition) New York:McGraw-Hill Company, 1976.
36. Fox, E.L., R.,. Bartels, C. Billings, R. Bason, and D. Matthews, "Frequency and Duration of Interval Training Programs and Changes in Aerobic Power", Journal of Applied Physiology, 38(3):481-484, 1975.
37. Fox, E.L., R.L. Bartels, C.E. Billings, D.K. Matthews, R. Bason and W.M. Webb, "Intensity and Distance of Interval Training Programs and Changes in Aerobic Power", Medicine and Science in Sport, 5(1):18-22, 1977.
38. Fox, E.L., R.L. Bartels, J. Klinzing, and K. Ragg, "Metabolic Responses to Interval Training Programs of High and Low Power Output", Medicine and Science in Sports, 9(3):191-196, 1977.
39. Fox, E.L., and D.L. Matthews, The Physiological Basis of Physical Education and Athletics (3rd. edition), Saunders College Publishing, Philadelphia, 1981.
40. Gettman, L.R., J.J. Ayres, M.L. Pollock and A. Jackson, "The Effect of Circuit Weight Training on Strength, Cardiorespiratory Function, and Body Composition", Medicine and Science in Sports, 10:171-176, 1978.
41. Gettman, L., P. Ward and R.D. Hagan, "Super Circuit Program", a reprint published by the Institute for Aerobics Research Study, November 1981.





42. Glassford, R.G., G.H.Y. Baycroft, A.W. Sedgwick and R.B.J. MacNab, "Comparison of Maximal Oxygen Uptake Values Determined by Predicted and Actual Methods", Journal of Applied Physiology, 20(3):509-513, 1965.
43. Hellebrandt, R.A., and J.J. Houtz, "Methods of Muscle Training The Influence of Pacing", The Physical Therapy Review, 38(5):319-322, 1958.
44. Hettinger, T.L., and E.A. Muller, "Muskelleistung and Muskeltraining", Arbeitsphysiologie, 15:111-126, 1953.
45. Hettinger, T., N.C. Birkhead, S.M. Horvath, B. Issekutz, K. Rodahl, "Assessment of Physical Work Capacity", Journal of Applied Physiology, 16:153-156, 1961.
46. Hill, A.V. and H. Lupton, "The Oxygen Consumption During Running", Journal of Physiology, 56:32-33, 1922.
47. Hislop, H.J., and J.J. Perrine, "The Isokinetic Concept of Exercise", Physical Therapy, 47:114-117, 1967.
48. Kasch, F.W., W.H. Philips, J.E.L. Carter and J.L. Boyer, "Cardio-vascular Changes in Middle Aged Men During Two Years of Training", Journal of Applied Physiology, 34:53-57, 1973.
49. Katch, F.I., and E.D. Michael, Jr., "Prediction of Body Density from Skinfold and Girth Measurements of College Females", Journal of Applied Physiology, 25:92-94, 1968.
50. Katch, F.I., "Practice Measurements and Errors of Measurement in Estimating Underwater Weight by Hydrostatic Weighing", Medicine and Science in Sports, 1:212-216, 1969.
51. Katch, F.I. and W.D. McCardle, "Prediction of Body Density From Simple Anthropometric Measurements in College Age Men and Women", Human Biology, 45:445-454, 1973.
52. Katch, F.I., "Measurement and Prediction Errors in Body Composition Assessment and the Search for the Perfect Prediction Equation", Research Quarterly, 51(1):249-260, 1980.
53. Kearney, J.T., G.A. Stull, J.L. Ewing, Jr., and J.W. Strein, "Cardio-respiratory Responses of Sedentary College Women as a Function of Training Intensity", Journal of Applied Physiology, 41:822-828, 1976.
54. Keys, A., and J. Brozek, "Body Fat in Adult Man", Physiological Reviews, 33:245-325, 1953.
55. Keul, J., G. Haralambie, M. Bruder, and H.J. Gottstein, "The Effect of Weightlifting Exercise on Heart rate and Metabolism in Experienced Weight Lifters", Medicine and Science in Sports, 10:13-15, 1978.



56. Kilbom, A., "Physical Training in Women", Scandinavian Journal of Clinical Laboratory Investigations 28, Suppl. 119, 1971.
57. Knuttgen, H.G., B. Ollander, L.O. Nordesjo and B. Saltin, "Interval Training and Physical Fitness of Young Male Adults", Medicine and Science in Sports, 4:59, 1972.
58. Magee, David J., The Effect of Isokinetic Exercise on Human Heart-rate and Blood Pressure, Doctoral Thesis, University of Alberta, 1980.
59. Manz, R.L. with R.L. Carnes and B. Carnes, The Hydra-Fitness Manual for Omnikinetic Training, Hydra Fitness Industries, Belton, Texas, 1982.
60. Mayhew, J.L. and P.M. Gross, "Body Composition Changes in Young Women with High Resistance Weight Training", Research Quarterly, 45(4):433, 1974.
61. McArdle, W.D. and G.F. Foglia, "Energy Cost and Cardiorespiratory Stress of Isometric and Weight Training Exercises", Journal of Sports Medicine, 9:23-30, 1969.
62. McMorris, R.O. and E.C. Elkins, "A study of Production and Evaluation of Muscle Hypertrophy", Archives of Physical Medicine and Rehabilitation, 35:420-426, 1954.
63. Meyers, C.R., "Effects of Two Isometric Routines on Strength, Size and Endurance in Exercised and Non-Exercised Arms", Research Quarterly, 38:430-439, 1967.
64. Miles, S., "Fit-For Anything", British Journal of Sports Medicine, 12:173-175, 1979.
65. Mitchell, J.H., B.J. Sproule and C.B. Chapman, "The Physiological Meaning of the Maximal Oxygen Intake Test", Journal of Clinical Investigations, 37:538-547, 1958.
66. Moffroid, M.R., R. Whipple, J. Hofkosh, E. Lowman and H. Thistle, "A Study of Isokinetic Exercise", Physical Therapy, 49:735-746, 1969.
67. Morris, J.N., "Evidence for the Benefits of Exercise from Epidemiological Studies", British Journal of Sports Medicine, 12:220-222, 1979.
68. Muller, E.A., and E. Rohmert, "Die Geschwindigkeit der Muskelkraft-Zunahme Bei", Internationale Zeitschrift Fur Angewandte Physiologie, 19:403-419, 1963.
69. Nagle, E.J., and L.W. Irwin, "The Effects of Two Systems of Weight Training On Circulo-Respiratory Endurance and Related Physiological Factors", Research Quarterly, 31:607-615, 1960.





70. Nupp, W.F., "The Relative Effectiveness of Four Cardiorespiratory Conditioning Programs", Journal of Sports Medicine, 10:84-90, 1970.
71. Pascale, L., M. Grossman, H. Sloane and T. Frankel, "Correlations Between Thickness of Skinfolts and Body Density in 88 Soldiers", Human Biology, 28:165-176, 1956.
72. Payne, F.E., "A Practical Approach to Effective Exercise", American Family Physician, 19(6):76-81, 1979.
73. Perrine, J.J., "Isokinetic Exercise and the Mechanical Energy Potentials of Muscle", Journal of Health, Physical Education and Recreation, 39:40-44, 1968.
74. Pipes, T.V. and J.H. Wilmore, "Isokinetic vs. Isotonic Strength Training in Adult Men", Medicine and Science in Sports, 7:262-274, 1975.
75. Pollock, M., T. Cureton, and L. Greninger, "Effects of Frequency of Training on Capacity, Cardiovascular Function and Body Composition of Adult Men", Medicine and Science in Sports, 1(2):70-74, 1969.
76. Pollock, M.L., "The Quantification of Endurance Training Programs", in J.H. Wilmore (ed.), Exercise and Sports Sciences Review, Vol. 1, p. 155, Academic Press Inc., New York, 1973.
77. Rasch, P.S., and L.E. Morehouse, "Effect of Static and Dynamic Exercise on Muscular Strength and Hypertrophy", Journal of Applied Physiology, 11:29-34, 1957.
78. Rathbun, F.N. and N. Pace, "Studies on Body Composition. I. Determination of Body Fat by Means of the Body Specific Gravity", Journal of Biological Chemistry, 158:667-676, 1945.
79. Roskamm, H., "Optimum Patterns of Exercise for Health Adults", Canadian Medical Association Journal, 96:895-899, 1967.
80. Salter, N., "The Effect on Muscle Strength of Maximum Isometric and Isotonic Contractions at Different Repetition Rates", Journal of Physiology, 130:109-113, 1955.
81. Saltin, B., and P.O. Astrand, "Maximal Oxygen Uptakes in Athletes", Journal of Applied Physiology, 23:353-358, 1967.
82. Saltin, B., B. Blomquist, J.H. Mitchell, R.L. Johnson Jr., K. Wildenthal and C.B. Chapman, "Response to Submaximal and Maximal Exercise after Bed Rest and Training", Circulation 38(Suppl. 7), 1968.
83. Saltin, B., L.H. Hartley, A. Kilbom and I. Astrand, "Physical Training in Sedentary Middle Aged and Older Men", Scandinavian Journal of Clinical Laboratory Investigations, 24:335-344, 1969.





84. Saltin, B., B. Essen, and P.K. Pederson, "Intermittent Exercise: Its Physiology and Some Practical Applications. In: Medicine and Sport, 9: Advances in Exercise Physiology, R.L. Anand, and H. Stoboy (eds.), Karger, Basel, 23-51, 1976.
85. Sheperd, R.J., "Exercise Prescription - North American Experience", British Journal of Sports Medicine, 12:227-234, 1976.
86. Siri, W.E., "The Gross Composition of the Body", in Advances in Biological and Medical Physics, edited by J.H. Lawrence and C.A. Tobias. London and New York:Academic Press Incorporated, 1956.
87. Siri, W.E., "Body Composition from Fluid Spaces and Density" In: Techniques for Measuring Body Composition (eds.) J. Brozek and A. Keys, National Academy of Science - National Research Council, Washington, 1961.
88. Sjostrand, T., "Changes in the Respiratory Organs of Workmen at an Ore Smelting Works", Acta Medica Scandinavica, Supplement 196:687-699, 1947.
89. Sloan, A.W., J.J. Burt and C.S. Blyth, "Estimation of Body Fat in Young Women", Journal of Applied Physiology, 17:967-970, 1962.
90. Standardized Test of Fitness Assessment Report, published by authority of the Minister of State, Fitness and Amateur Sport, Canada
91. Taylor, H.L., E. Buskirk and A. Henschel, "Maximal Oxygen Intake as an Objective Measure of Cardio-Respiratory Performance", Journal of Applied Physiology, 8:73-80, 1955.
92. Thistle, H.G., H.J. Hislop, M. Moffroid, and E.W. Lawman, "Isokinetic Contraction: A New Concept of Resistance Exercise", Archives of Physical Medicine and Rehabilitation, 48:279-282, 1967.
93. Tornvall, G., "Assessment of Physical Capabilities with Special Reference to the Evaluation of Maximal Voluntary Isometric Muscle Strength and Maximal Working Capacity: An Experimental Study on Civilian and Military Subject Groups", Acta Physiologica Scandinavica, 58(Suppl. 201):1-102, 1963.
94. Wahlund, H., "Determination of the Physical Working Capacity", Acta Medica Scandinavica, Supplement 215:1-78, 1948.
95. Wenger, H.A., and R.B.J. MacNab, "Endurance Training: The Effects of Intensity, Total Work, Duration and Initial Fitness", Journal of Sports Medicine, 15:199-211, 1975.
96. Wilmore, J.H., "Alteration in Strength, Body Composition and Anthropometric Measurements Consequent to a 10 Week Training Program", Medicine and Science in Sports, 6:133-138, 1974.



97. Wilmore, J.H. and A.R. Behnke, "An Anthropometric Estimation of Body Density and Lean Body Weight in Young Men", Journal of Applied Physiology, 27:25-31, 1969.
98. Wilmore, J.H. and A.R. Behnke, "An Anthropometric Estimation of Body Density and Lean Body Weight in Young Women", American Journal of Clinical Nutrition, 23:267-274, 1970.
99. Syndham, C.H., N. Stydom and B. Maritz, "Maximum Oxygen Intake and Maximum Heartrate During Strenuous Work", Journal of Applied Physiology, 14:927-936, 1959.
100. Wyndham, C.H., "Submaximal Tests for Estimating Maximum Oxygen Intake", Canadian Medical Association Journal, 96:736-742, 1967.
101. Young, C.M., E.K. Martin, R. Tensuan and J. Blondin, "Predicting Specific Gravity and Body Fatness in Young Women", Journal of the American Dietetic Association, 40:102-107, 1962.
102. Yuhasz, M., "The Effects of Sports Training on Body Fat in Men, with Predictions of Optimal Body Weight", Doctoral Dissertation, University of Illinois, Urbana, 1962.
103. Zinovieff, A.N., "Heavy Resistance Exercises: The Oxford Technique", British Journal of Physical Medicine, 14:129-132, 1951.



APPENDIX A

PHOTOGRAPHS OF HYDRAULIC RESISTIVE APPARATUS  
USED IN THE TRAINING PROGRAM







POWER SQUAT







BENCH PRESS





PRO POWER



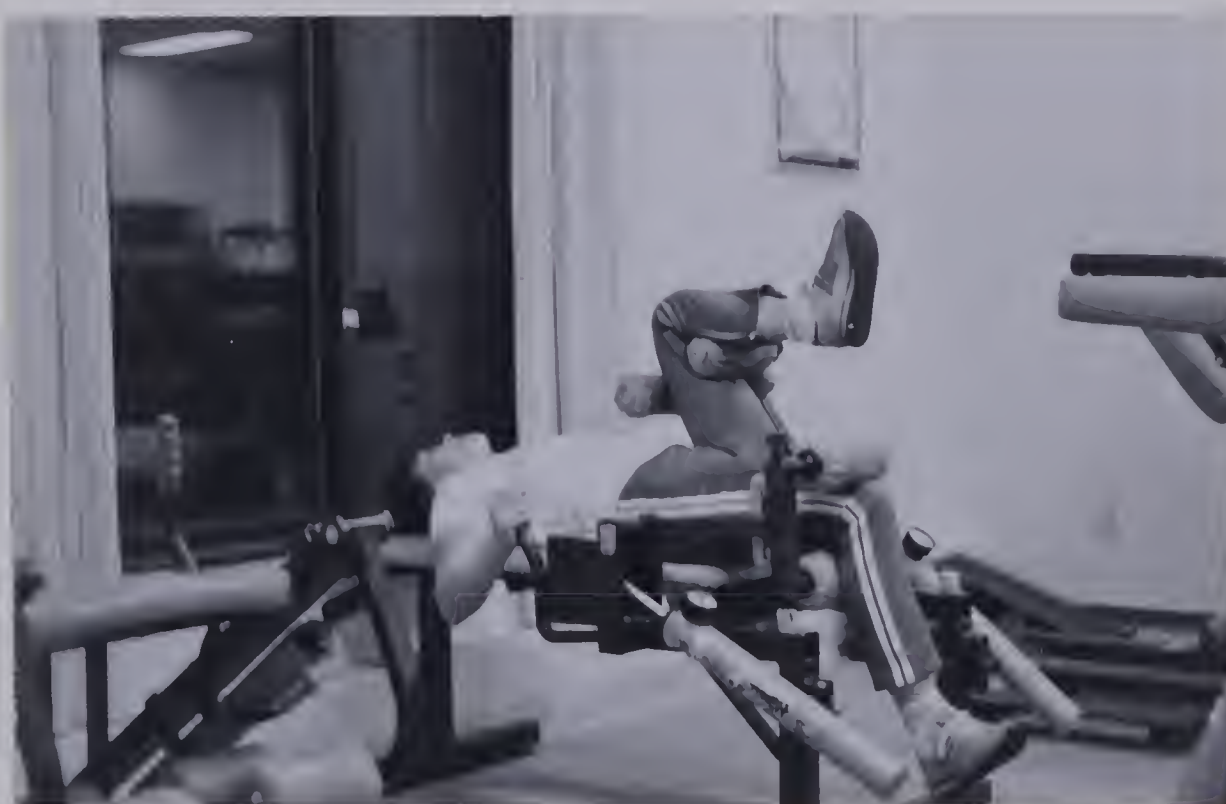


POWER BUTTERFLY









POWER RUNNER





SHOULDER PRESS





UNI-LATERAL KNEE







ARM CURLS







SIT-UPS





ABDUCTOR-ADDUCTOR



APPENDIX B

FORMS UTILIZED IN THE PROGRAM





## PERSONAL INFORMATION

NAME: \_\_\_\_\_ AGE: \_\_\_\_\_

SEX:     M     F     Height: \_\_\_\_\_ Weight: \_\_\_\_\_

Phone #                      Home \_\_\_\_\_ Work \_\_\_\_\_

1. Are you currently involved in any regular activity? If so what and how often:

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---



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---

2. How long have you been involved in the above activity?

---



---

3. If currently inactive, how long has it been since you were involved in any regular activity?

---



---

4. Do you smoke? \_\_\_\_\_ If so, how much and for how long? \_\_\_\_\_

5. Have you ever been through a fitness test before? \_\_\_\_\_ If yes, how long ago? \_\_\_\_\_

6. Are you presently on any medication? \_\_\_\_\_

If yes, what and for what condition? \_\_\_\_\_

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7. Further comments: \_\_\_\_\_

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Date: \_\_\_\_\_ Signature: \_\_\_\_\_



To: ALL PARTICIPANTS

From: Diane Satre

Prior to your testing session would you please note the following instructions:

1. Do not smoke within ONE hour of the test.
2. Do not drink coffee or tea (or other beverages containing caffeine) within one hour of your testing session.
3. Do not eat within one hour of the test. If you cannot avoid eating, please eat lightly.
4. Do not consume any alcoholic beverages within twenty-four hours of your test.
5. Do not exercise strenuously within twenty-four hours of your test.



## CONSENT FORM FOR EXERCISE TESTING

I, \_\_\_\_\_, authorize Diane Satre and her assistants to administer and conduct a series of tests designed to assess cardio-respiratory capacity, strength and per cent body fat.

I understand that the test for assessing cardiovascular capacity will involve performing on a bicycle ergometer at two submaximal, progressive workloads, each being four minutes in duration. Throughout this eight minutes my heartrate will be monitored using an Exersentry and the resistance setting on the bicycle during the final four minutes will be set so as to illicit a heartrate response between 70% and 85% of my maximum heartrate, as estimated according to my age.

I also understand that for assessing strength, I will perform a series of six exercises, four upper body exercises and two lower body exercises. I will perform one repetition, of maximal effort, for each exercise, using two different exercise systems: the Universal Gym and Nautilus equipment. I will also perform three repetitions of maximal exercise for each exercise using the Hydra-Gym equipment.

Per cent body fat will be determined using a series of skinfold measurements.

These tests will be discontinued if I become distressed in any way or develop any abnormal response. Every effort will be made to conduct these tests in such a manner that any risk or discomfort is minimized, however, I understand that there are potential risks with these tests which include transient lightheadedness, faintness, leg cramps, chest discomfort and extremely rarely, heart attack.

In agreeing to participate in these tests, I waive any legal recourse against Diane Satre and her assistants, the Northern Alberta Institute of Technology, or the Edmonton Fitness Centre, for any personal injuries sustained or from death resulting from these tests. This waiver shall be binding upon my heirs and my personal representatives.

Date: \_\_\_\_\_ Signature: \_\_\_\_\_

Witness: \_\_\_\_\_





PAR-Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problems or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check the YES opposite the question if it applies to you.

YES

- ☐ 1. Has your doctor ever said you have heart trouble?
- ☐ 2. Do you frequently have pains in your heart and chest?
- ☐ 3. Do you often feel faint or have spells of severe dizziness?
- ☐ 4. Has a doctor ever said your blood pressure was too high?
- ☐ 5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise or might be made worse with exercise?
- ☐ 6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
- ☐ 7. Are you over age 65 and not accustomed to vigorous exercise?

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q or show him your copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:

unrestricted physical activity, probably on a gradual increasing basis.

restricted or supervised activity to meet your specific needs, at least on an initial basis.

Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

A GRADUATED EXERCISE PROGRAM

A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort.

AN EXERCISE TEST - Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire.

Postpone

If you have a temporary minor illness, such as a common cold.

SIGNED.....

DATE.....

I consent to participate in an exercise test





## EXERCISE TESTING DATA SHEET

NAME: \_\_\_\_\_ DATE: \_\_\_\_\_

Age: \_\_\_\_\_ Weight: \_\_\_\_\_ kg. Sex: M F

1. Cardiorespiratory Data

Astrand (modified): Resting H.R. \_\_\_\_\_ Resting B.P. \_\_\_\_\_ Bike # \_\_\_\_\_

| Min. | Load | H.R. | B.P. |  | Min. | Load | H.R. | B.P. |
|------|------|------|------|--|------|------|------|------|
| 1    |      |      |      |  | 5    |      |      |      |
| 2    |      |      |      |  | 6    |      |      |      |
| 3    |      |      |      |  | 7    |      |      |      |
| 4    |      |      |      |  | 8    |      |      |      |

Recovery: H.R. \_\_\_\_\_ 3 min. B.P. \_\_\_\_\_ 3 min.

Predicted  $\dot{V}O_2$  max \_\_\_\_\_ l./min x A.C.F. \_\_\_\_\_ l./min. \_\_\_\_\_ ml./kg/min.2. Body Composition DataTest 1 (Pascale) $X_1$   $X_2$   $X_3$ 

|           |  |  |  |
|-----------|--|--|--|
| 1.        |  |  |  |
| 2.        |  |  |  |
| 3.        |  |  |  |
| $\bar{x}$ |  |  |  |

 $\Sigma =$ Test 2 (Durnin) $X_1$   $X_2$   $X_3$   $X_4$ 

|           |  |  |  |  |
|-----------|--|--|--|--|
| 1.        |  |  |  |  |
| 2.        |  |  |  |  |
| 3.        |  |  |  |  |
| $\bar{x}$ |  |  |  |  |

 $\Sigma =$ 3. Strength Data

Hydra-Gym

Nautilus

Universal/Free Wts.

| Exercise                              | Resistance |  |  | Resistance | Resistance |
|---------------------------------------|------------|--|--|------------|------------|
| Total Power (Shoulders) <sup>up</sup> |            |  |  |            |            |
| Arm Curls                             |            |  |  |            |            |
| Total Power (Legs)                    |            |  |  |            |            |
| Bench Press (Up)                      |            |  |  |            |            |
| Total Power (Lat.pull)                |            |  |  |            |            |
| Power Squat (Leg Press)               |            |  |  |            |            |



CONSENT FORM FOR PARTICIPATION IN TRAINING PROGRAM

I, \_\_\_\_\_, hereby give my consent to participate in a training program designed by Diane Satre for use on the Hydra-Gym equipment, a type of variable resistance exercise equipment.

I understand that I will train 3 times per week for a period of 10 weeks. Each training session I will perform up to 3 circuits of 10 exercises involving various pieces of equipment. For each exercise I will work as fast as I can for 20 seconds, at a resistance between 40% and 60% of my maximum strength. Following the 20 second work interval, I will have a 40 second relief interval during which time I will prepare for the next exercise. I will continue in this manner throughout the workout for a total workout time of 30 minutes.

I acknowledge that I have been informed of and fully understand all the specific details associated with the training procedures. I have also been familiarized with the equipment I will be training on.

I fully understand as it has been explained to me that by notice given to the undersigned investigator that I may withdraw from this research project any time that I may elect to do so.

I further acknowledge that I have been informed of the potential health risks associated with a program of this nature.

In agreeing to participate in this training program, I waive any legal recourse against Diane Satre and her assistants, or against The Edmonton Fitness Centre, for any personal injuries sustained or from death resulting from this program. This waiver shall be binding upon my heirs and my personal representatives.

Date: \_\_\_\_\_ Signature: \_\_\_\_\_

Witness: \_\_\_\_\_

I hereby certify that I have given to the above individual an explanation of the contemplated study and any possible side effects.

Investigator's Signature: \_\_\_\_\_



APPENDIX C

THREE WAY ANALYSES ON POST-TEST  $\text{VO}_2\text{MAX}$   
AND PER CENT BODY FAT





TABLE XIII

THREE WAY ANALYSIS OF VARIANCE - POST-TEST  $\text{VO}_2\text{MAX}$  BY  
TREATMENT, SEX AND INITIAL  $\text{VO}_2\text{MAX}$

| Source of Variation | Sum of Squares | DF | Mean Square | F      | Significance of F |
|---------------------|----------------|----|-------------|--------|-------------------|
| Main Effects        | 2202.036       | 3  | 734.012     | 14.908 | 0.000             |
| Treatment           | 655.879        | 1  | 655.879     | 13.321 | 0.001             |
| Sex                 | 433.452        | 1  | 433.452     | 8.803  | 0.004             |
| Fit                 | 1467.774       | 1  | 1467.774    | 29.811 | 0.000             |
| 2-Way Interactions  |                |    |             |        |                   |
| Tr Sex              | 35.233         | 3  | 11.744      | 0.239  | 0.869             |
| Tr Sex              | 23.573         | 1  | 23.573      | 0.479  | 0.492             |
| Sex Fit             | 4.454          | 1  | 4.454       | 0.090  | 0.765             |
|                     | 0.560          | 1  | 0.560       | 0.011  | 0.915             |
| 3-Way Interactions  |                |    |             |        |                   |
| Tr Sex Fit          | 73.813         | 1  | 73.813      | 1.499  | 0.226             |
|                     | 73.813         | 1  | 73.813      | 1.499  | 0.226             |
| Explained           | 2311.081       | 7  | 330.154     | 6.705  | 0.000             |
| Residual            | 2806.485       | 57 | 49.237      |        |                   |
| Total               | 5117.566       | 64 | 79.962      |        |                   |



TABLE XIV

THREE WAY ANALYSIS OF VARIANCE - POST-TEST VO<sub>2</sub>MAX  
BY TREATMENT, AGE LEVEL AND INITIAL VO<sub>2</sub>MAX<sup>2</sup>

| Source of Variation | Sum of Squares | DF | Mean Square | F      | Signif of F |
|---------------------|----------------|----|-------------|--------|-------------|
| Main Effects        | 2275.926       | 3  | 758.642     | 16.009 | 0.000       |
| Treatment           | 891.214        | 1  | 891.214     | 18.806 | 0.000       |
| Aged                | 507.342        | 1  | 507.342     | 10.706 | 0.002       |
| Fit                 | 805.254        | 1  | 805.254     | 16.993 | 0.000       |
| 2-Way Interactions  | 134.858        | 3  | 44.953      | 0.949  | 0.423       |
| Tr Aged             | 0.013          | 1  | 0.013       | 0.000  | 0.987       |
| Tr Fit              | 30.899         | 1  | 30.899      | 0.652  | 0.423       |
| Aged Fit            | 83.265         | 1  | 83.265      | 1.757  | 0.190       |
| 3-Way Interactions  |                |    |             |        |             |
| Tr Aged Fit         | 5.624          | 1  | 5.624       | 0.119  | 0.732       |
|                     | 5.624          | 1  | 5.624       | 0.119  | 0.732       |
| Explained           | 2416.407       | 7  | 345.201     | 7.284  | 0.000       |
| Residual            | 2701.159       | 57 | 47.389      |        |             |
| Total               | 5117.566       | 64 | 79.962      |        |             |



TABLE XV

THREE WAY ANALYSIS OF VARIANCE - POST-TEST PER CENT BODY FAT  
BY TREATMENT, SEX AND INITIAL PER CENT BODY FAT

| Source of Variation | Sum of Squares | DF | Mean Square | F      | Significance of F |
|---------------------|----------------|----|-------------|--------|-------------------|
| Main Effects        | 1411.305       | 3  | 470.435     | 34.914 | 0.000             |
| Treatment           | 85.464         | 1  | 85.464      | 6.343  | 0.015             |
| Sex                 | 110.664        | 1  | 110.664     | 8.213  | 0.006             |
| Body Fat Per Cent   | 373.669        | 1  | 373.669     | 27.732 | 0.000             |
| 2-Way Interactions  | 14.921         | 3  | 4.974       | 0.369  | 0.776             |
| Tr Sex              | 4.560          | 1  | 4.560       | 0.338  | 0.563             |
| Tr BFPR             | 13.822         | 1  | 13.822      | 1.026  | 0.315             |
| Sex BFPR            | 0.060          | 1  | 0.060       | 0.004  | 0.947             |
| 3-Way Interactions  |                |    |             |        |                   |
| Tr Sex BFPR         | 0.214          | 1  | 0.016       | 0.016  | 0.900             |
|                     | 0.214          | 1  | 0.016       | 0.016  | 0.900             |
| Explained           | 1426.441       | 7  | 203.777     | 15.123 | 0.000             |
| Residual            | 768.030        | 57 | 13.474      |        |                   |
| Total               | 2194.471       | 64 | 34.289      |        |                   |



TABLE XVI

THREE WAY ANALYSIS OF VARIANCE - POST-TEST PER CENT BODY FAT  
BY TREATMENT, AGE LEVEL AND INITIAL PER CENT BODY FAT

| Source of Variation | Sum of Squares | DF | Mean Square | F       | Significance of F |
|---------------------|----------------|----|-------------|---------|-------------------|
| Main Effects        | 1419.455       | 3  | 473.152     | 41.340  | 0.000             |
| Treatment           | 150.469        | 1  | 150.469     | 13.147  | 0.001             |
| Aged                | 118.814        | 1  | 118.814     | 10.381  | 0.002             |
| Body Fat Per Cent   | 1277.051       | 1  | 1277.051    | 111.577 | 0.0               |
| 2-Way Interactions  | 69.429         | 3  | 23.143      | 2.022   | 0.121             |
| Tr Aged             | 31.724         | 1  | 31.724      | 2.772   | 0.101             |
| Tr BFPR             | 45.886         | 1  | 45.886      | 4.009   | 0.050             |
| Aged BFPR           | 1.129          | 1  | 1.129       | 0.099   | 0.755             |
| 3-Way Interactions  | 53.197         | 1  | 53.197      | 4.648   | 0.035             |
| Tr Aged BFPR        | 53.197         | 1  | 53.197      | 4.648   | 0.035             |
| Explained           | 1542.081       | 7  | 220.297     | 19.248  | 0.000             |
| Residual            | 652.390        | 57 | 11.445      |         |                   |
| Total               | 2194.471       | 64 | 34.289      |         |                   |





#### APPENDIX D

POST-TEST MEANS FOR THREE WAY ANALYSES ON POST-TEST  $VO_2$  MAX  
AND PER CENT BODY FAT:TWO WAY COMBINATIONS



TABLE XVII

GROUP MEANS FOR THREE WAY ANALYSES ON POST-TEST  
 $\text{VO}_2\text{MAX}$ : TWO WAY COMBINATIONS

| Group                   | N  | Post-Test<br>$\bar{x}$ |
|-------------------------|----|------------------------|
| Control/Initially High  | 10 | 42.78                  |
| Control/Initially Low   | 19 | 31.85                  |
| Training/Initially High | 10 | 47.10                  |
| Training/Initially Low  | 26 | 39.08                  |
| Control/Old             | 6  | 28.67                  |
| Control/Young           | 23 | 39.96                  |
| Training/Old            | 15 | 36.67                  |
| Training/Young          | 21 | 44.62                  |
| Old/Initially High      | 4  | 38.20                  |
| Old/Initially Low       | 17 | 33.47                  |
| Young/Initially High    | 16 | 46.75                  |
| Young/Initially Low     | 28 | 37.11                  |
| Control/Female          | 13 | 33.92                  |
| Control/Male            | 16 | 36.31                  |
| Training/Female         | 16 | 39.38                  |
| Training/Male           | 20 | 42.00                  |
| Female/Initially High   | 12 | 43.33                  |
| Male/Initially High     | 28 | 48.00                  |
| Female/Initially Low    | 17 | 32.41                  |
| Male/Initially Low      | 8  | 38.00                  |



TABLE XVIII

GROUP MEANS FOR THREE WAY ANALYSES ON POST-TEST  
PER CENT BODY FAT: TWO WAY COMBINATIONS

| Group                   | N  | Post-Test<br>$\bar{x}$ |
|-------------------------|----|------------------------|
| Control/Initially High  | 13 | 26.57                  |
| Control/Initially Low   | 16 | 16.70                  |
| Training/Initially High | 19 | 23.05                  |
| Training/Initially Low  | 17 | 15.12                  |
| Control/Old             | 6  | 22.32                  |
| Control/Young           | 23 | 20.81                  |
| Training/Old            | 15 | 21.13                  |
| Training/Young          | 21 | 17.99                  |
| Old/Initially High      | 10 | 25.12                  |
| Old/Initially Low       | 11 | 18.16                  |
| Young/Initially High    | 22 | 24.18                  |
| Young/Initially Low     | 22 | 14.75                  |
| Control/Female          | 13 | 25.71                  |
| Control/Male            | 16 | 17.39                  |
| Training/Female         | 16 | 23.43                  |
| Training/Male           | 20 | 16.29                  |
| Female/Initially High   | 25 | 25.37                  |
| Male/Initially High     | 7  | 21.27                  |
| Female/Initially Low    | 4  | 18.70                  |
| Male/Initially Low      | 29 | 15.50                  |





APPENDIX E

RAW DATA



TABLE XIX

## RAW DATA FOR CONTROL SUBJECTS

| Subjects | Age | % Body Fat |           | Max $\dot{V}O_2$ |           |
|----------|-----|------------|-----------|------------------|-----------|
|          |     | Pre-Test   | Post-Test | Pre-Test         | Post-Test |
| *1       | 27  | 22.64      | 23.06     | 39               | 41        |
| 2        | 31  | 22.38      | 24.70     | 22               | 19        |
| 3        | 23  | 26.31      | 27.11     | 30               | 30        |
| 4        | 24  | 30.28      | 31.30     | 27               | 27        |
| 5        | 39  | 37.63      | 37.45     | 25               | 25        |
| 6        | 30  | 19.68      | 18.77     | 43               | 42        |
| 7        | 29  | 22.00      | 23.31     | 49               | 46        |
| 8        | 27  | 28.24      | 25.89     | 31               | 33        |
| 9        | 34  | 19.75      | 19.20     | 39               | 41        |
| 10       | 24  | 26.56      | 26.52     | 34               | 30        |
| 11       | 23  | 28.58      | 29.54     | 36               | 33        |
| 12       | 34  | 27.87      | 26.61     | 33               | 32        |
| 13       | 32  | 21.78      | 20.80     | 35               | 42        |
|          |     |            |           |                  |           |
| **1      | 44  | 18.80      | 18.87     | 40               | 34        |
| 2        | 40  | 20.20      | 21.44     | 21               | 25        |
| 3        | 35  | 20.67      | 19.06     | 26               | 28        |
| 4        | 33  | 16.37      | 16.35     | 45               | 38        |
| 5        | 34  | 15.12      | 14.69     | 42               | 43        |
| 6        | 34  | 19.60      | 19.73     | 28               | 30        |
| 7        | 42  | 19.85      | 19.09     | 33               | 35        |
| 8        | 30  | 13.33      | 14.75     | 40               | 39        |
| 9        | 19  | 14.56      | 14.75     | 39               | 33        |
| 10       | 20  | 10.98      | 12.01     | 54               | 50        |
| 11       | 29  | 13.83      | 13.72     | 51               | 51        |
| 12       | 34  | 13.18      | 13.29     | 31               | 29        |
| 13       | 20  | 11.25      | 10.92     | 40               | 44        |
| 14       | 19  | 28.35      | 30.00     | 41               | 37        |
| 15       | 28  | 17.24      | 18.58     | 42               | 40        |
| 16       | 40  | 19.76      | 20.74     | 25               | 25        |

\* 1 - 13 Females

\*\* 1 - 16 Males



TABLE XX

## RAW DATA FOR TRAINING SUBJECTS

| Subjects | Age | % Body Fat |           | Max V0 <sub>2</sub> |           |
|----------|-----|------------|-----------|---------------------|-----------|
|          |     | Pre-Test   | Post-Test | Pre-Test            | Post-Test |
| *1       | 30  | 20.03      | 17.25     | 41                  | 52        |
| 2        | 25  | 26.70      | 25.03     | 31                  | 35        |
| 3        | 22  | 27.36      | 27.07     | 33                  | 40        |
| 4        | 34  | 21.07      | 20.90     | 47                  | 48        |
| 5        | 45  | 39.56      | 35.93     | 15                  | 23        |
| 6        | 23  | 20.96      | 20.63     | 51                  | 52        |
| 7        | 38  | 27.50      | 27.01     | 31                  | 35        |
| 8        | 29  | 23.40      | 23.21     | 35                  | 30        |
| 9        | 39  | 27.15      | 24.28     | 35                  | 36        |
| 10       | 27  | 25.40      | 21.07     | 35                  | 39        |
| 11       | 37  | 24.62      | 22.67     | 32                  | 43        |
| 12       | 31  | 22.92      | 21.04     | 42                  | 46        |
| 13       | 37  | 23.95      | 23.01     | 39                  | 38        |
| 14       | 34  | 22.85      | 22.82     | 36                  | 36        |
| 15       | 24  | 20.50      | 19.58     | 32                  | 42        |
| 16       | 27  | 24.41      | 23.39     | 31                  | 35        |
|          |     |            |           |                     |           |
| **1      | 40  | 18.45      | 16.30     | 33                  | 41        |
| 2        | 34  | 16.50      | 14.10     | 35                  | 38        |
| 3        | 33  | 15.33      | 14.59     | 39                  | 43        |
| 4        | 44  | 19.48      | 17.98     | 26                  | 34        |
| 5        | 35  | 21.36      | 18.58     | 43                  | 45        |
| 6        | 37  | 24.84      | 22.84     | 19                  | 24        |
| 7        | 32  | 11.88      | 10.72     | 51                  | 51        |
| 8        | 19  | 14.63      | 14.46     | 52                  | 57        |
| 9        | 26  | 15.47      | 13.83     | 43                  | 51        |
| 10       | 32  | 21.14      | 18.95     | 45                  | 55        |
| 11       | 34  | 11.28      | 9.92      | 44                  | 42        |
| 12       | 29  | 13.60      | 12.10     | 48                  | 56        |
| 13       | 35  | 23.82      | 21.03     | 38                  | 45        |
| 14       | 19  | 18.06      | 17.15     | 34                  | 43        |
| 15       | 36  | 18.73      | 17.96     | 40                  | 40        |
| 16       | 35  | 14.44      | 13.98     | 22                  | 32        |
| 17       | 43  | 20.25      | 19.56     | 31                  | 37        |
| 18       | 40  | 17.74      | 17.46     | 38                  | 53        |
| 19       | 42  | 22.13      | 18.42     | 24                  | 24        |
| 20       | 28  | 10.05      | 10.03     | 40                  | 46        |

\* 1 - 16 Females

\*\* 1 - 20 Males



APPENDIX F

BODY WEIGHTS FOR TRAINING SUBJECTS





TABLE XXI

## BODY WEIGHTS FOR TRAINING SUBJECTS

| Subjects | Age | Pre-Test<br>Weight (kg) | Post-Test<br>Weight (kg) |
|----------|-----|-------------------------|--------------------------|
| *1       | 30  | 53.6                    | 49.5                     |
| 2        | 25  | 64.5                    | 64.5                     |
| 3        | 22  | 63.5                    | 65.0                     |
| 4        | 34  | 58                      | 58.0                     |
| 5        | 45  | 84                      | 83.0                     |
| 6        | 23  | 61                      | 63.2                     |
| 7        | 38  | 68.2                    | 69.1                     |
| 8        | 29  | 54.75                   | 56.0                     |
| 9        | 39  | 62.0                    | 61.0                     |
| 10       | 27  | 53.50                   | 55.2                     |
| 11       | 37  | 60.2                    | 60.5                     |
| 12       | 31  | 49.5                    | 50.0                     |
| 13       | 37  | 61.25                   | 61.5                     |
| 14       | 34  | 58.0                    | 58.0                     |
| 15       | 24  | 57.4                    | 57.0                     |
| 16       | 27  | 62.2                    | 57.3                     |
| **1      | 40  | 73.3                    | 73.5                     |
| 2        | 34  | 77.0                    | 76.2                     |
| 3        | 33  | 76.6                    | 77.1                     |
| 4        | 44  | 84.5                    | 85.3                     |
| 5        | 35  | 80.3                    | 78.0                     |
| 6        | 37  | 105.0                   | 105.4                    |
| 7        | 32  | 75.6                    | 73.5                     |
| 8        | 19  | 81.7                    | 80.7                     |
| 9        | 26  | 74.0                    | 72.0                     |
| 10       | 32  | 84.8                    | 83.6                     |
| 11       | 34  | 77.3                    | 77.5                     |
| 12       | 29  | 85.0                    | 82.0                     |
| 13       | 35  | 85.0                    | 85.0                     |
| 14       | 19  | 82.6                    | 81.0                     |
| 15       | 36  | 87.5                    | 86.0                     |
| 16       | 35  | 61.7                    | 62.8                     |
| 17       | 43  | 96.3                    | 94.5                     |
| 18       | 40  | 78.0                    | 79.1                     |
| 19       | 42  | 89.3                    | 82.1                     |
| 20       | 28  | 67.2                    | 68.2                     |

\* 1 - 16 Females

\*\* 1 - 20 Males





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